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**Mishra et al.**

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(54) **WIRELESS LAN POWER SAVINGS**

(71) Applicant: **Marvell International Ltd.**, Hamilton  
(BM)

(72) Inventors: **Partho Mishra**, Cupertino, CA (US);  
**Sandesh Goel**, Fremont, CA (US)

(73) Assignee: **Marvell International LTD.**, Hamilton  
(BM)

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continuation of application No. 11/351,232, filed on  
Feb. 9, 2006, now Pat. No. 7,881,755.

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(52) **U.S. Cl.**  
CPC ..... **H04W 52/0216** (2013.01); **H04W 52/0225**  
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(58) **Field of Classification Search**  
None  
See application file for complete search history.

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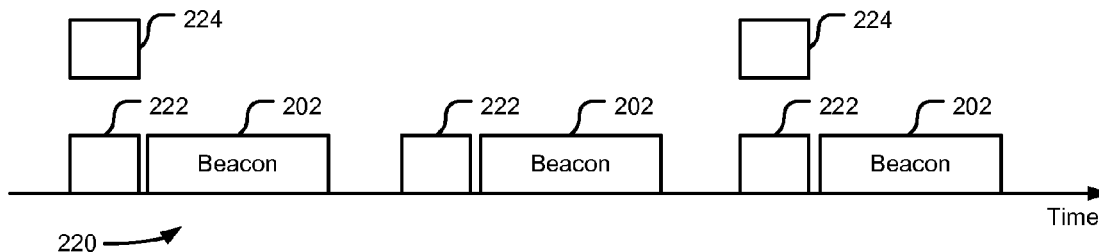
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*Primary Examiner* — Khoa Huynh

(57) **ABSTRACT**

An access point configured to be implemented in a wireless  
network, the access point including a beacon module and a  
transmit module. The access point is configured to commu-  
nicate with one or more client stations in the wireless net-  
work. The beacon module is configured to generate (i) a first  
beacon and (ii) a second beacon, wherein the first beacon is  
shorter in duration than the second beacon. The transmit  
module is configured to periodically transmit, to the one or  
more client stations in the wireless network, each of the first  
beacon and the second beacon. Each time the first beacon and  
the second beacon are transmitted by the transmit module, the  
first beacon is transmitted prior to the second beacon.

**18 Claims, 27 Drawing Sheets**



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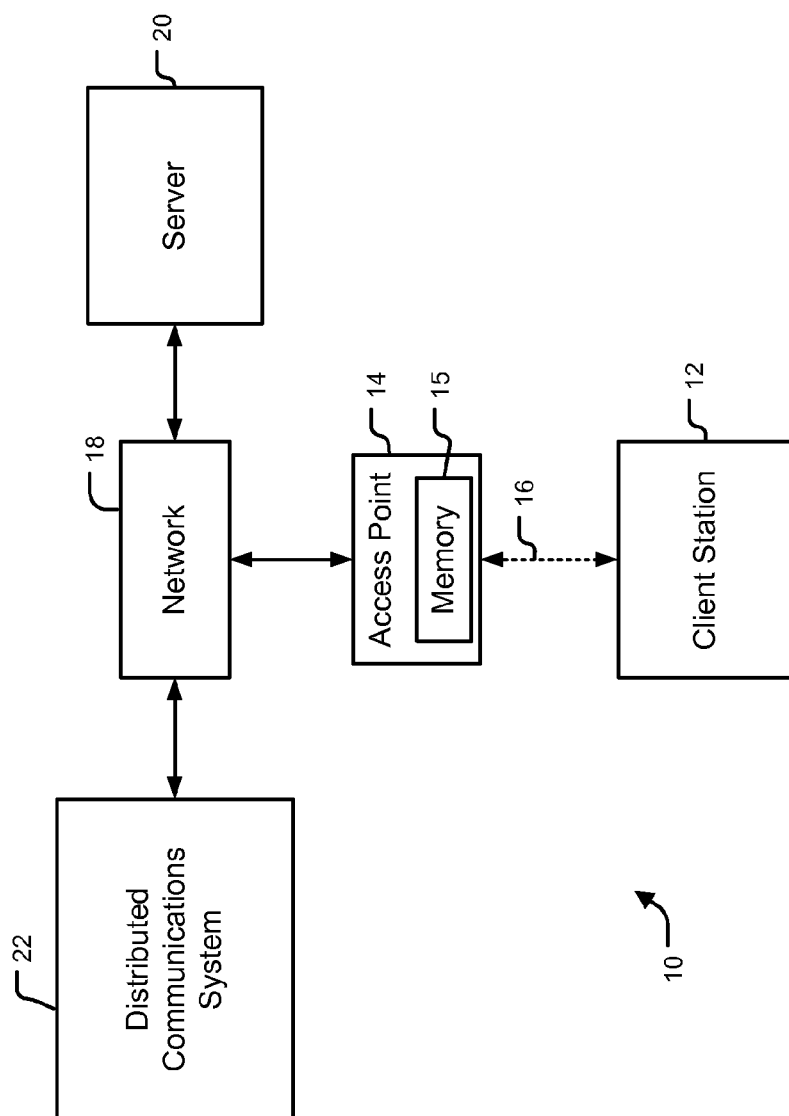
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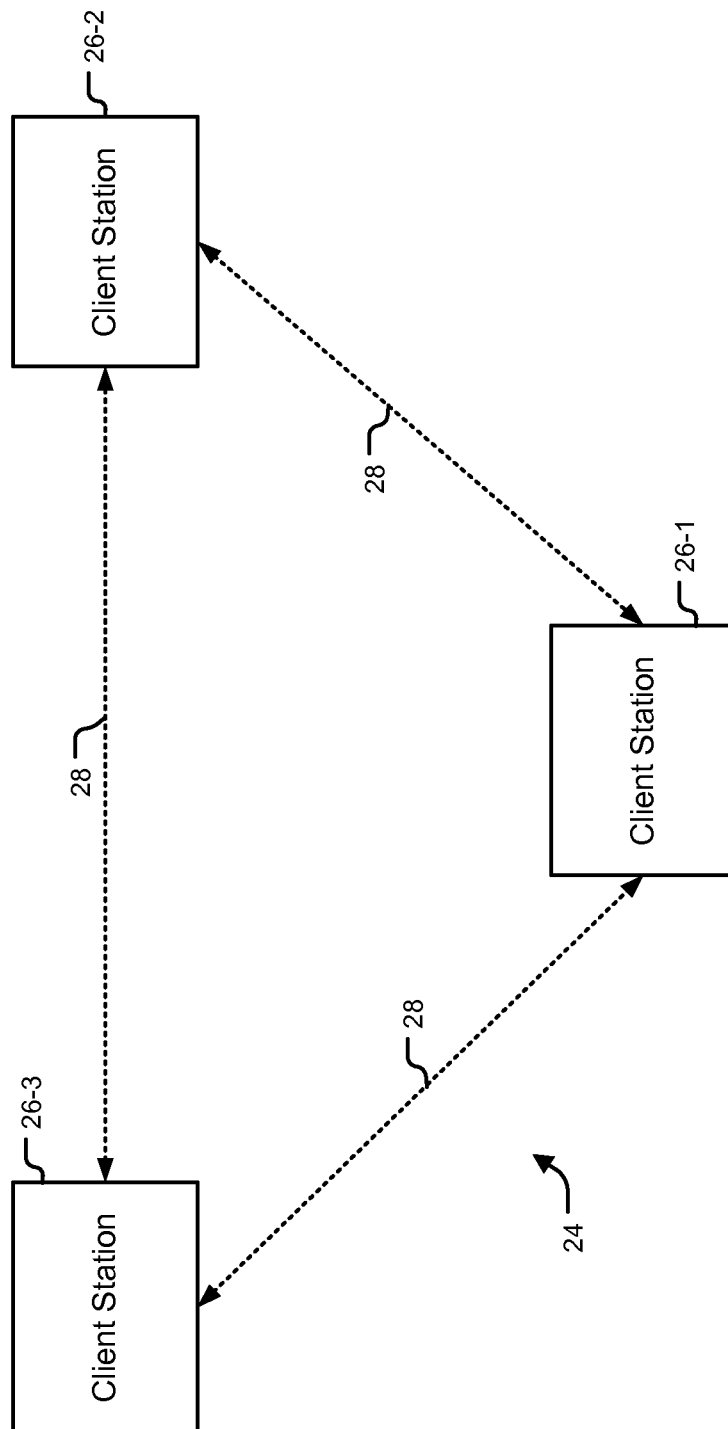
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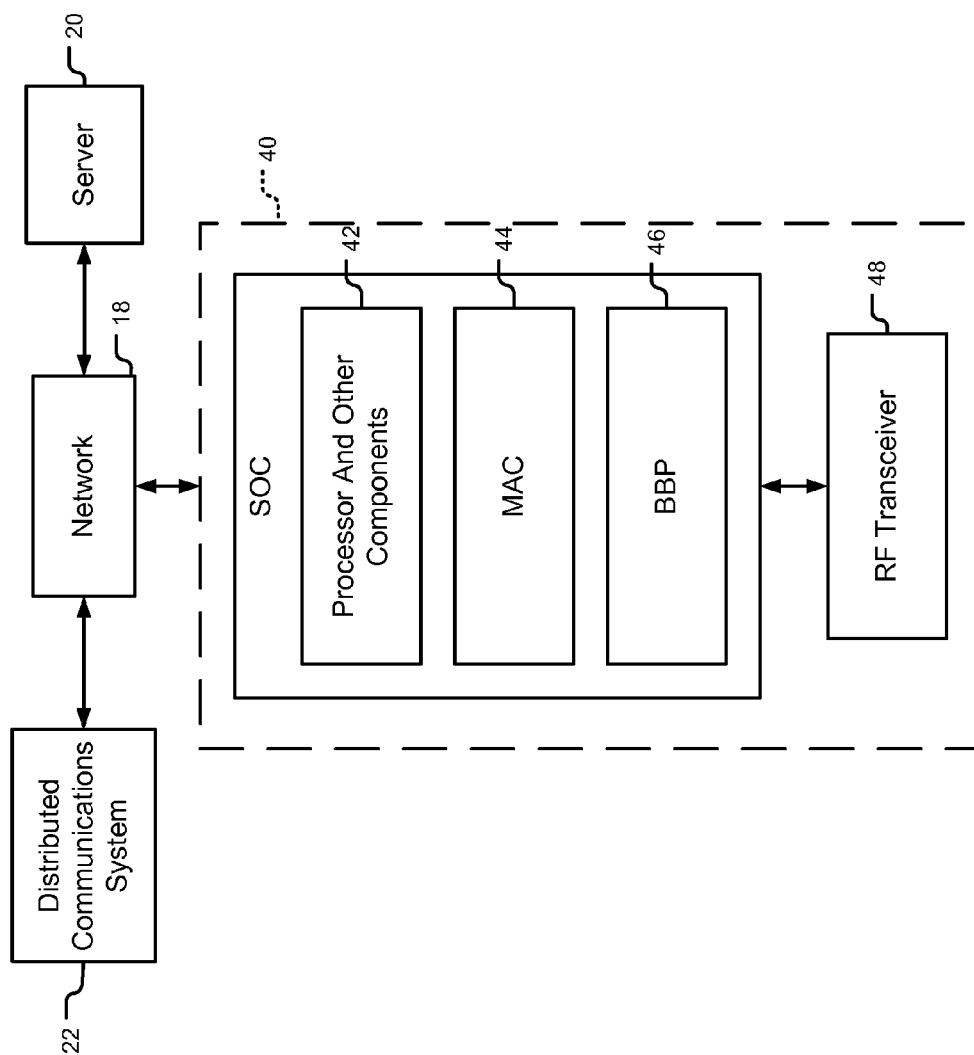
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**FIG. 1**  
Prior Art



**FIG. 2**  
Prior Art



**FIG. 3**  
Prior Art

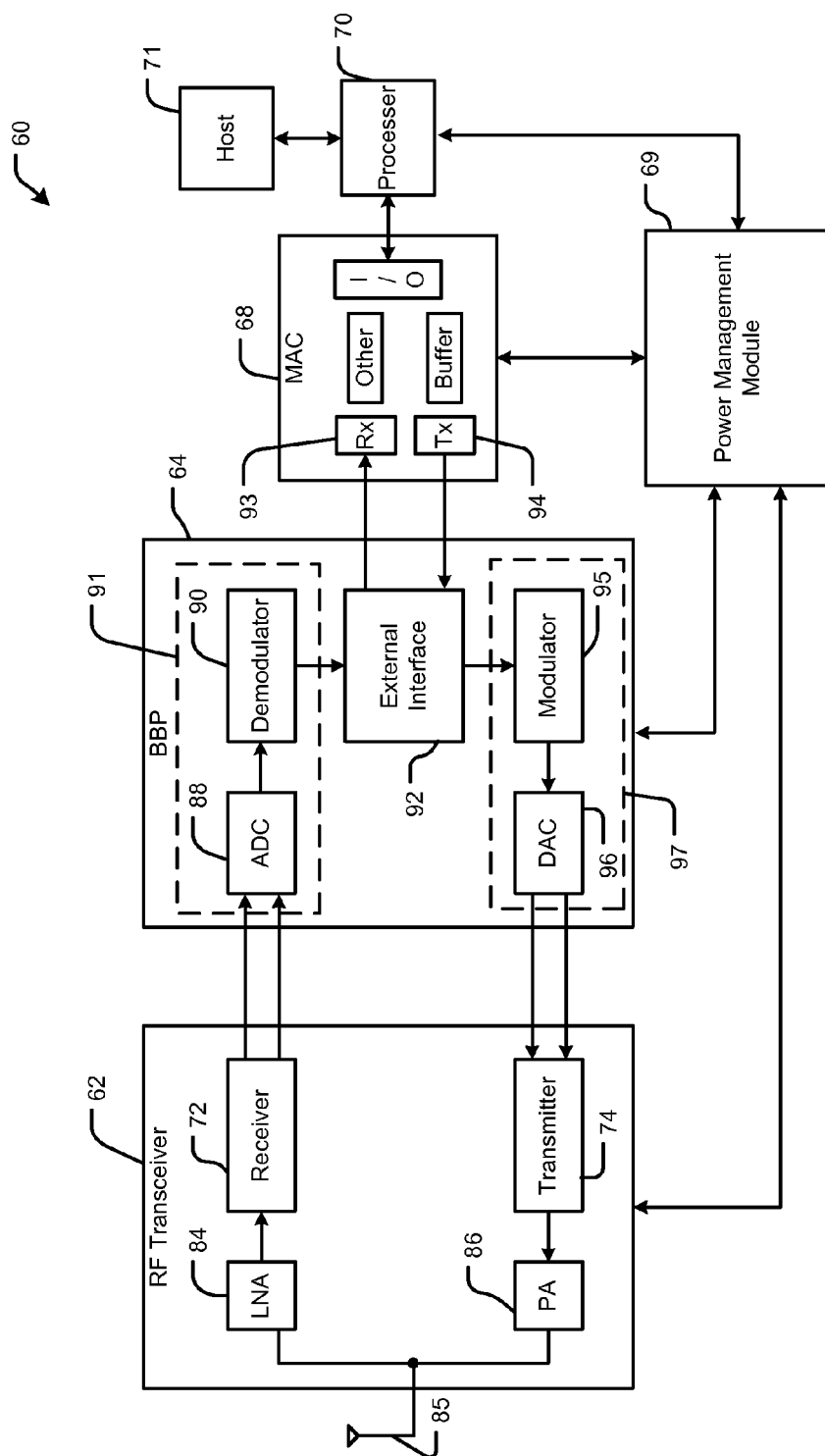


FIG. 4

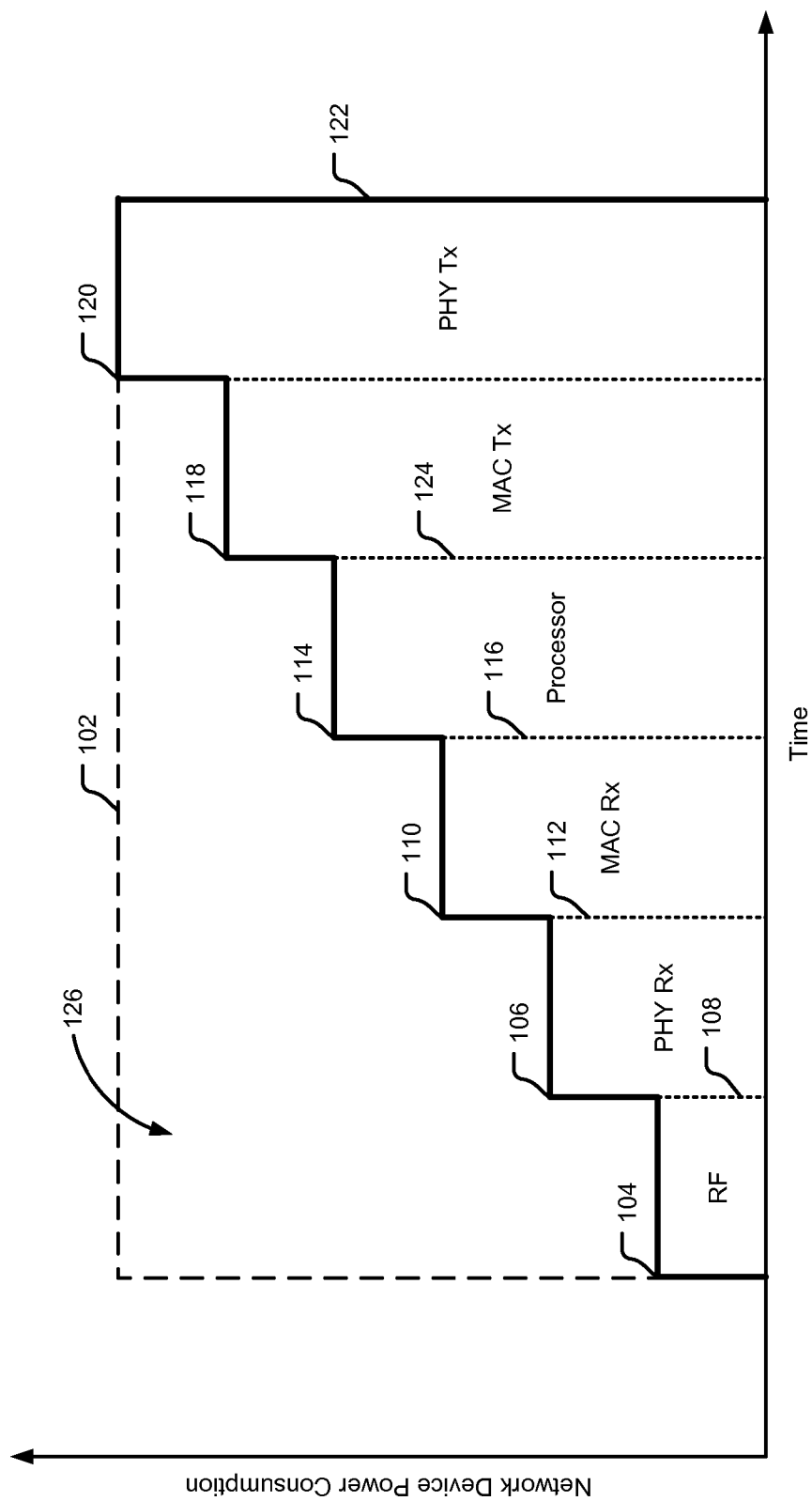


FIG. 5

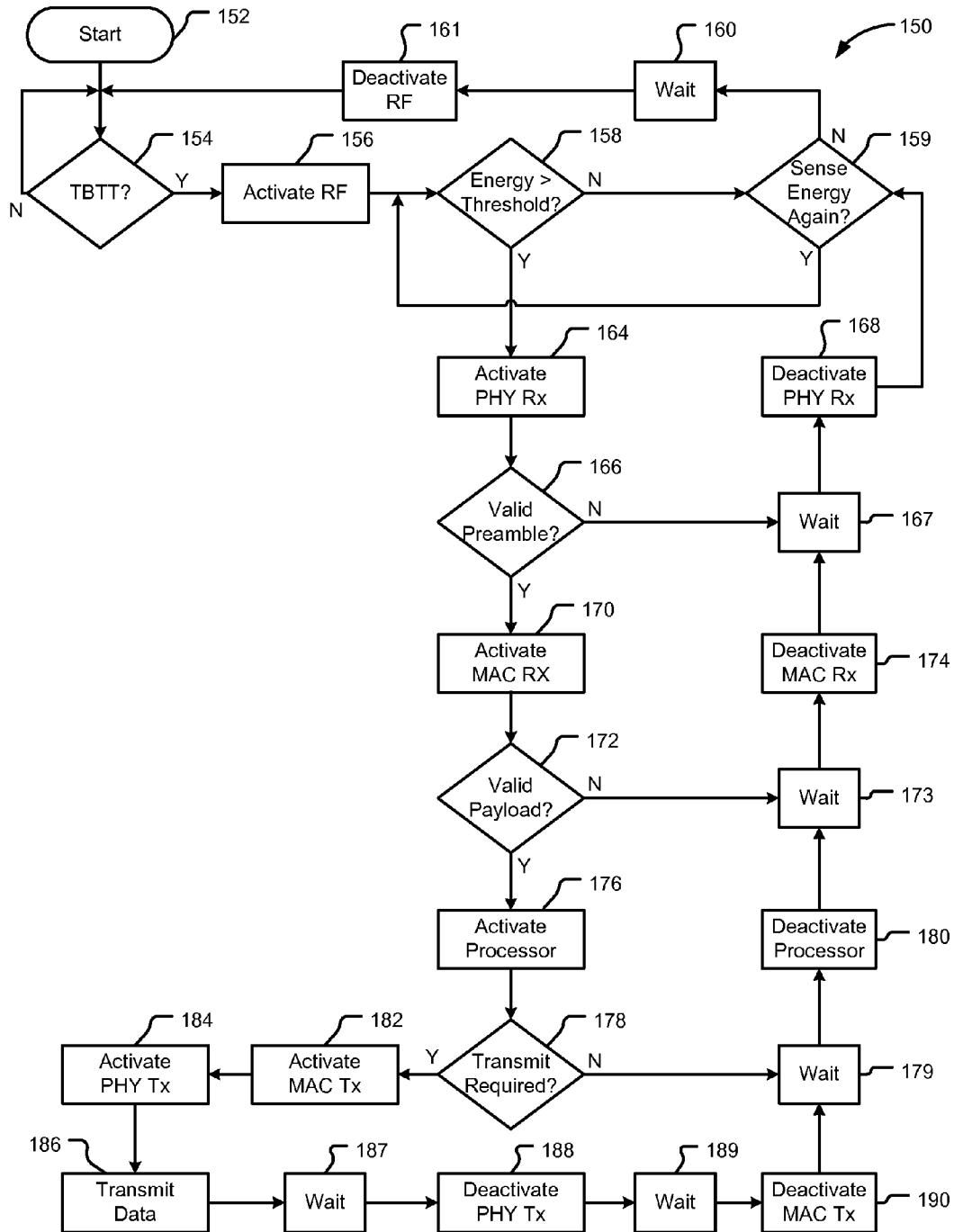
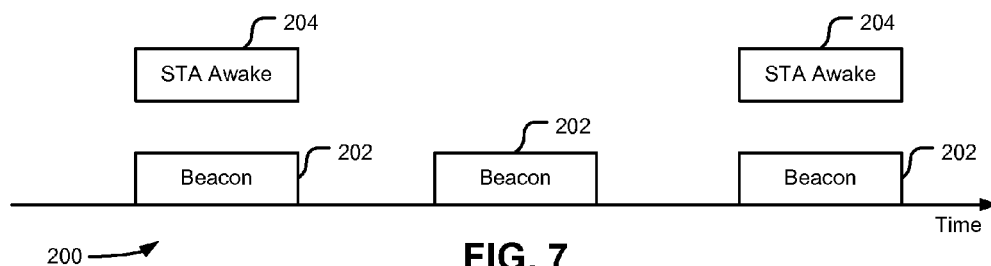
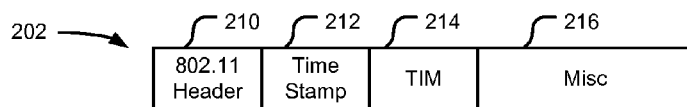


FIG. 6

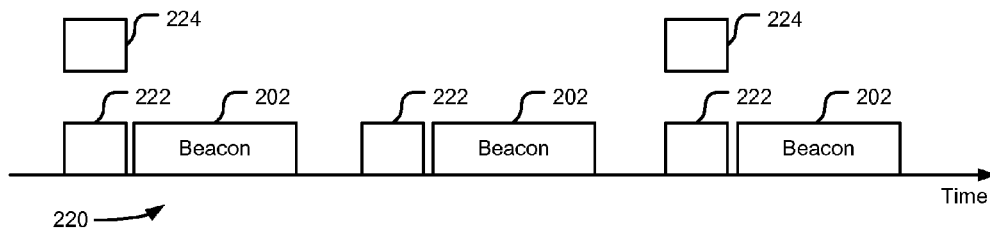




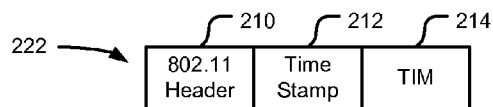
**FIG. 7**  
Prior Art



**FIG. 8**  
Prior Art



**FIG. 9**



**FIG. 10**

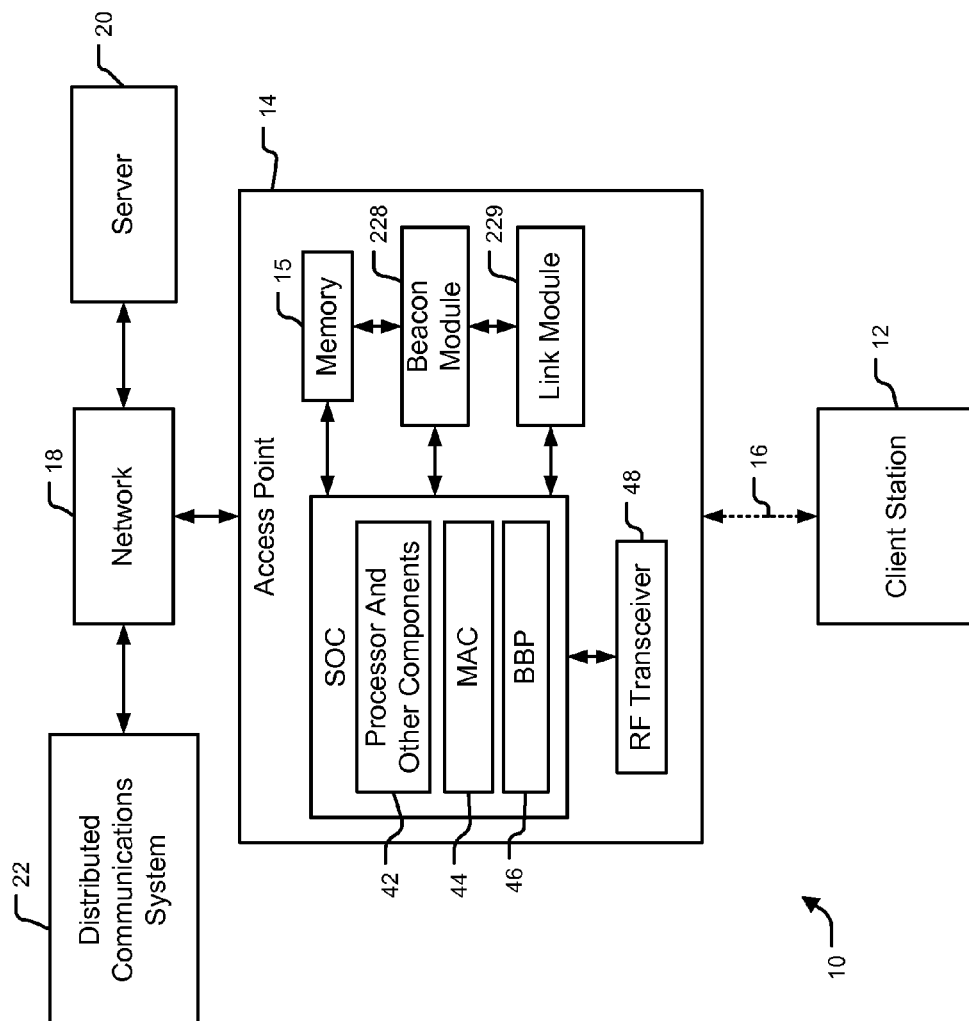


FIG. 11

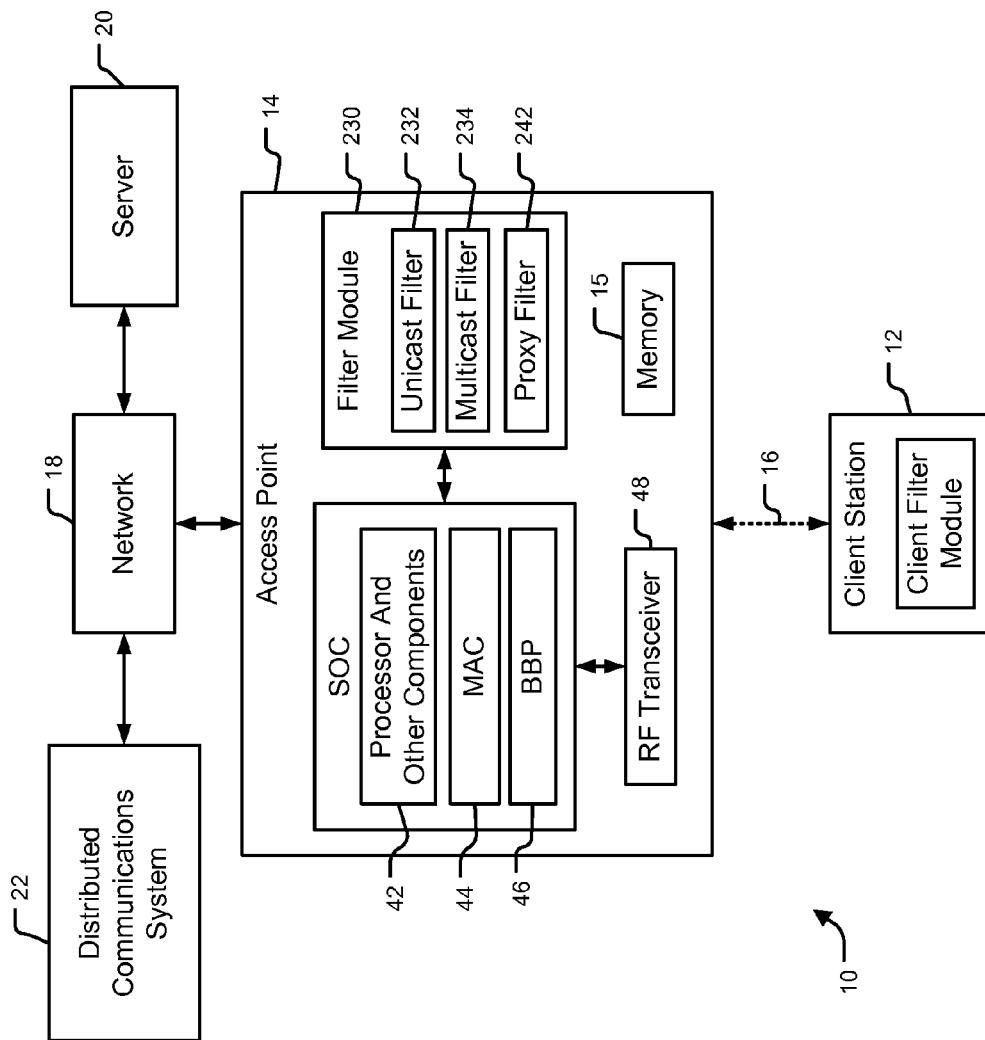
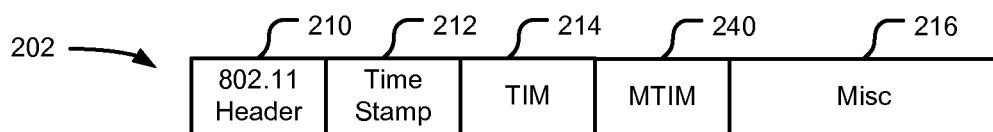
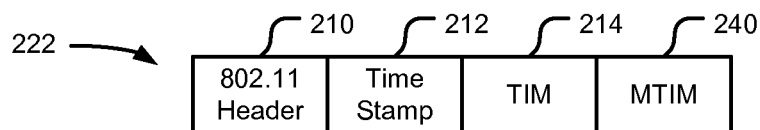


FIG. 12



**FIG. 13A**



**FIG. 13B**

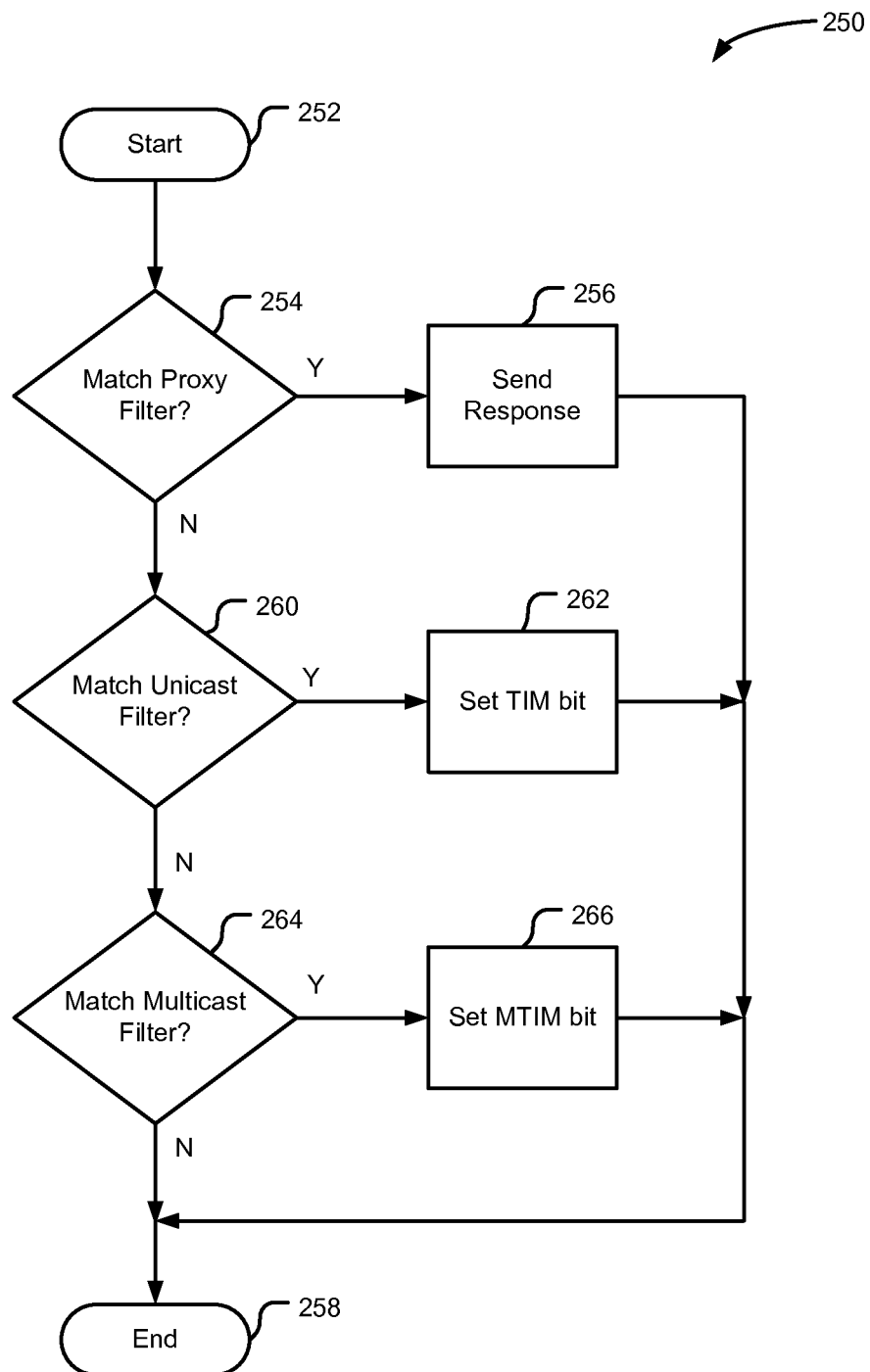
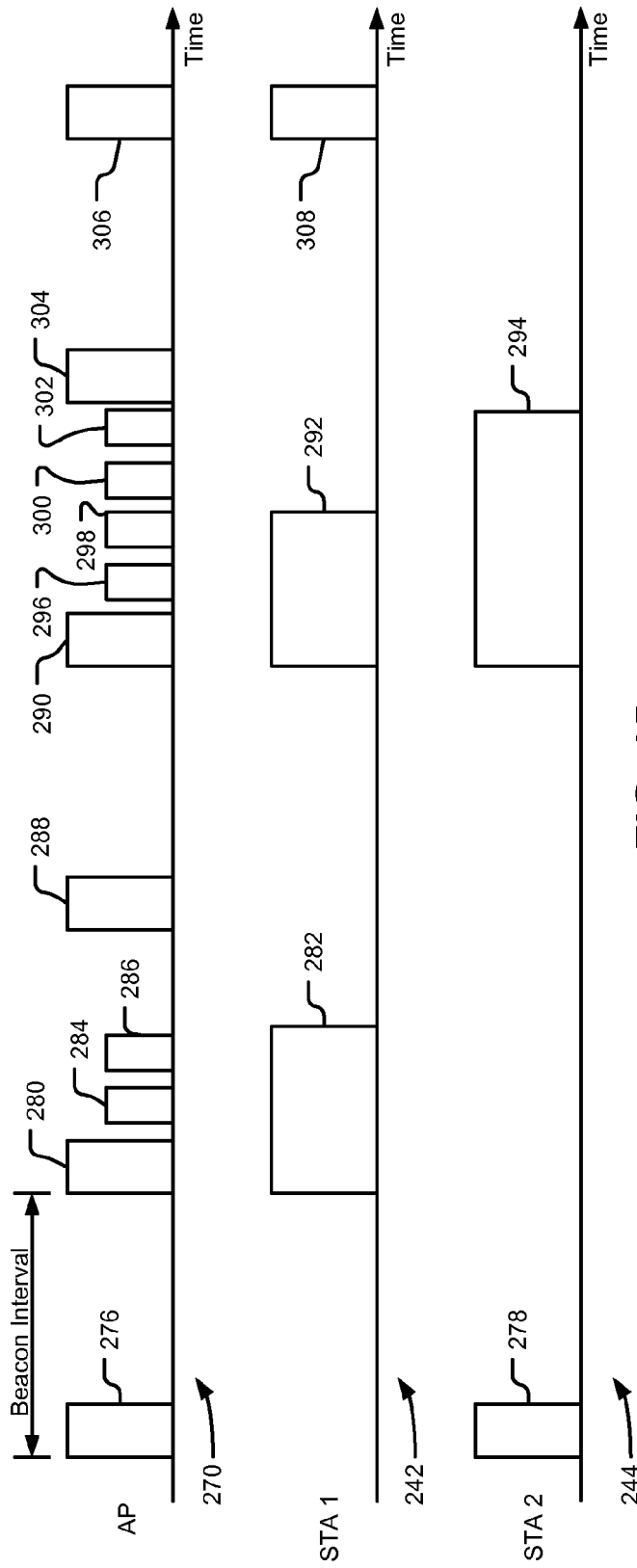


FIG. 14



**FIG. 15**  
Prior Art

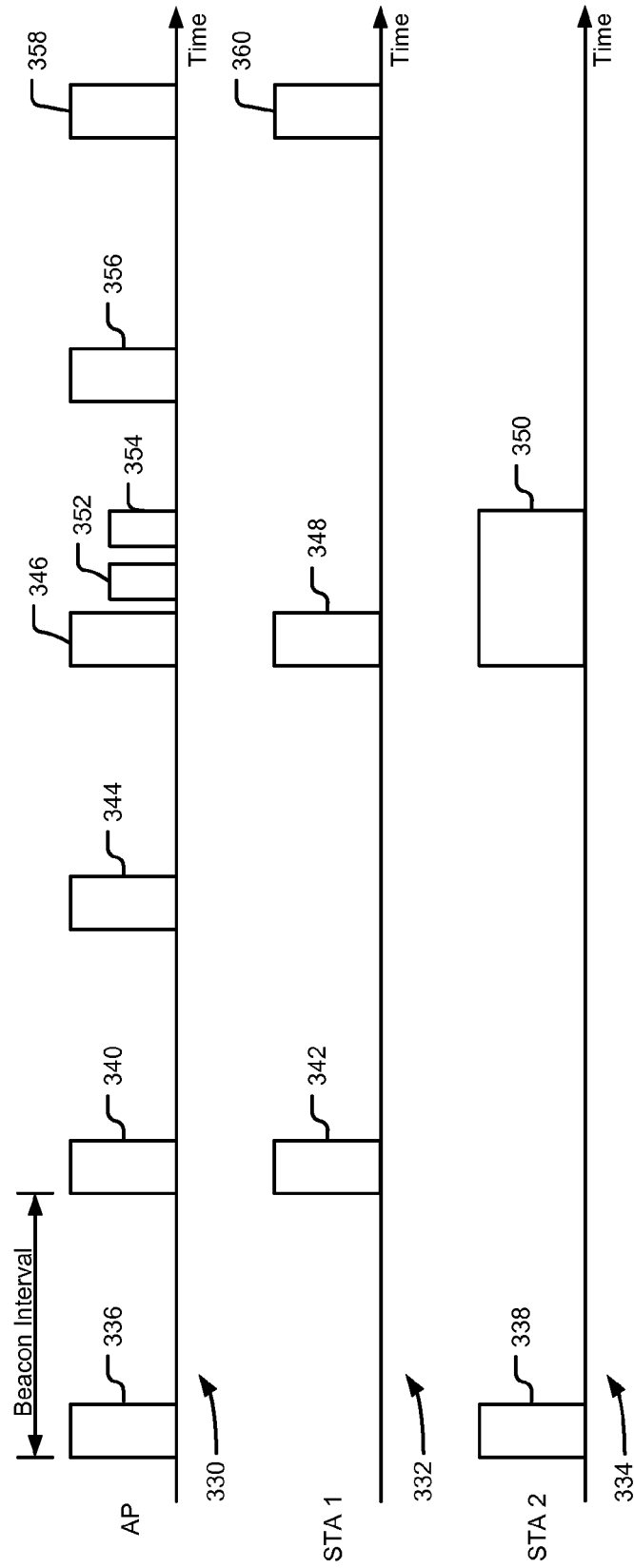
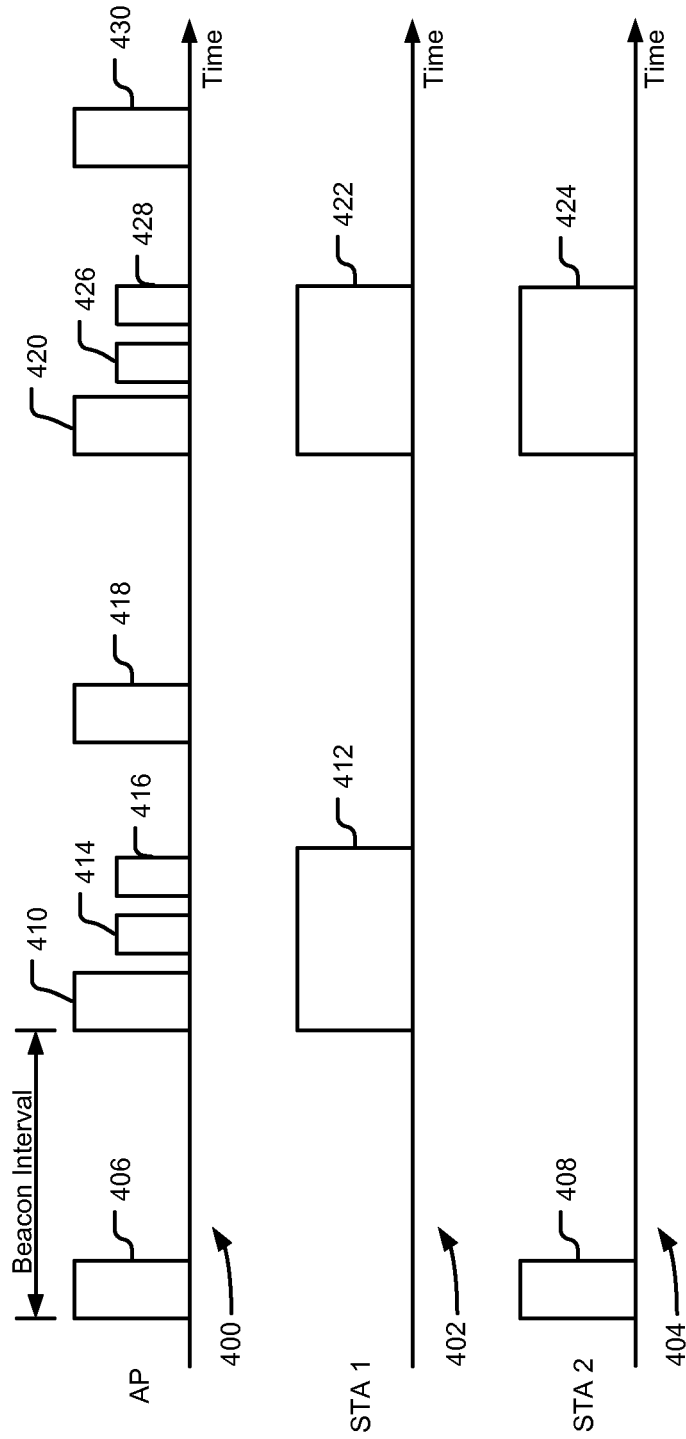


FIG. 16



**FIG. 17**  
Prior Art



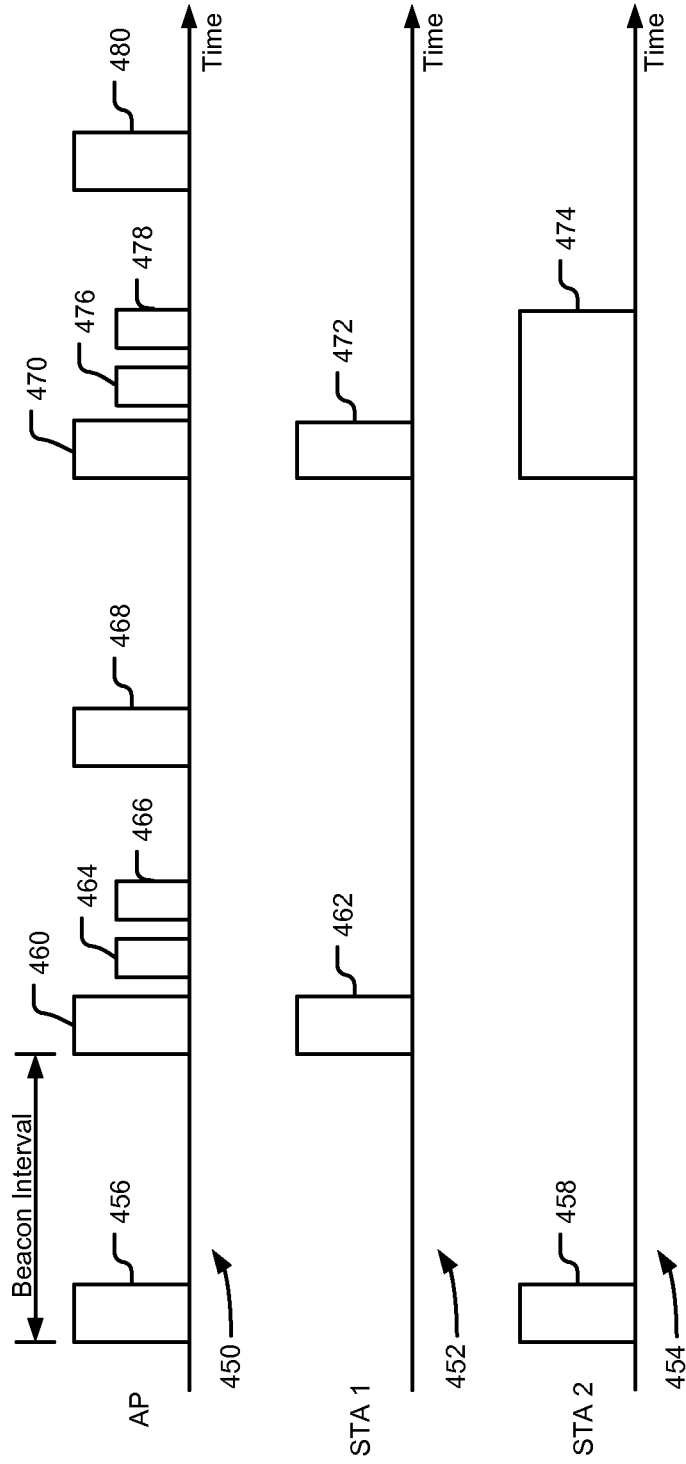
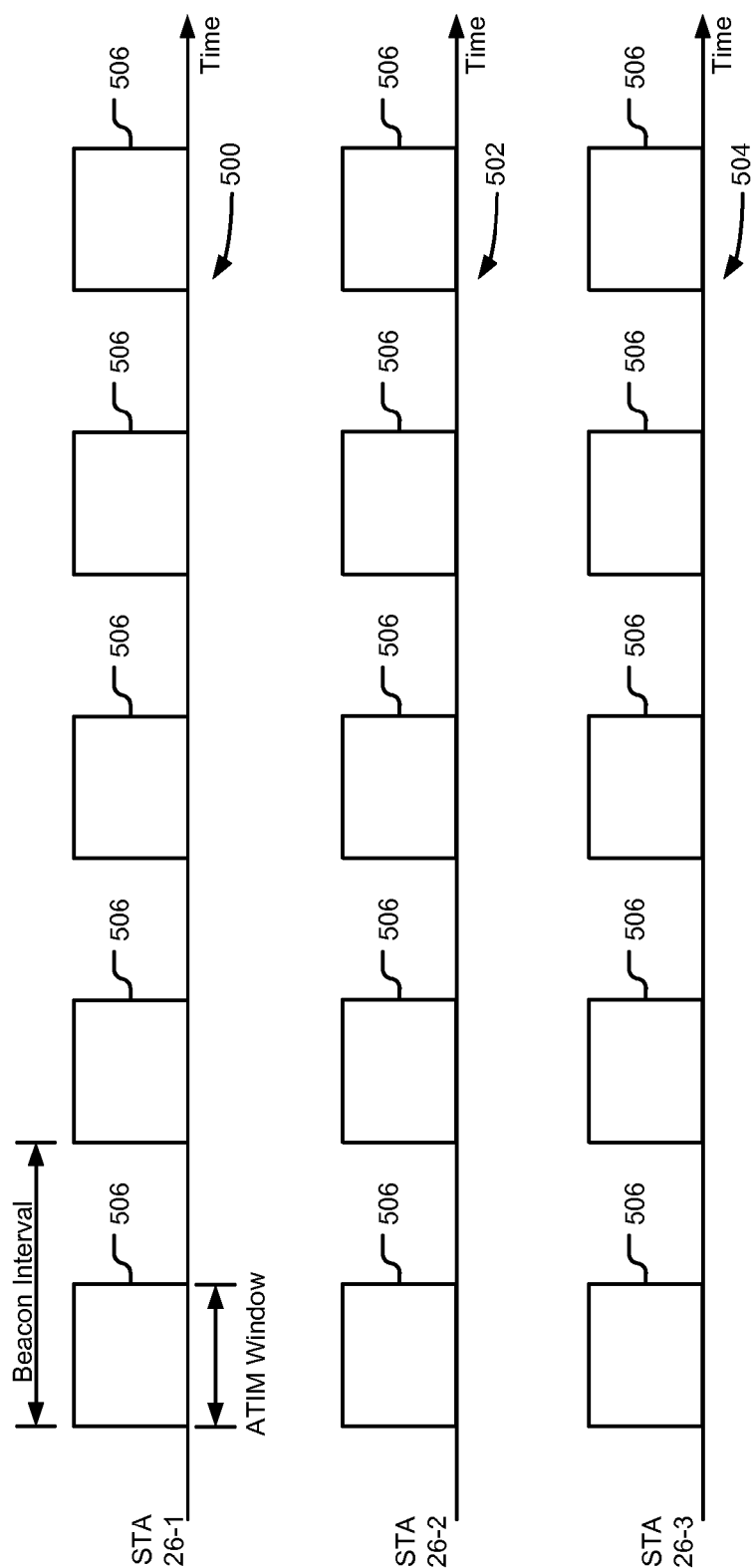


FIG. 18



**FIG. 19**  
Prior Art

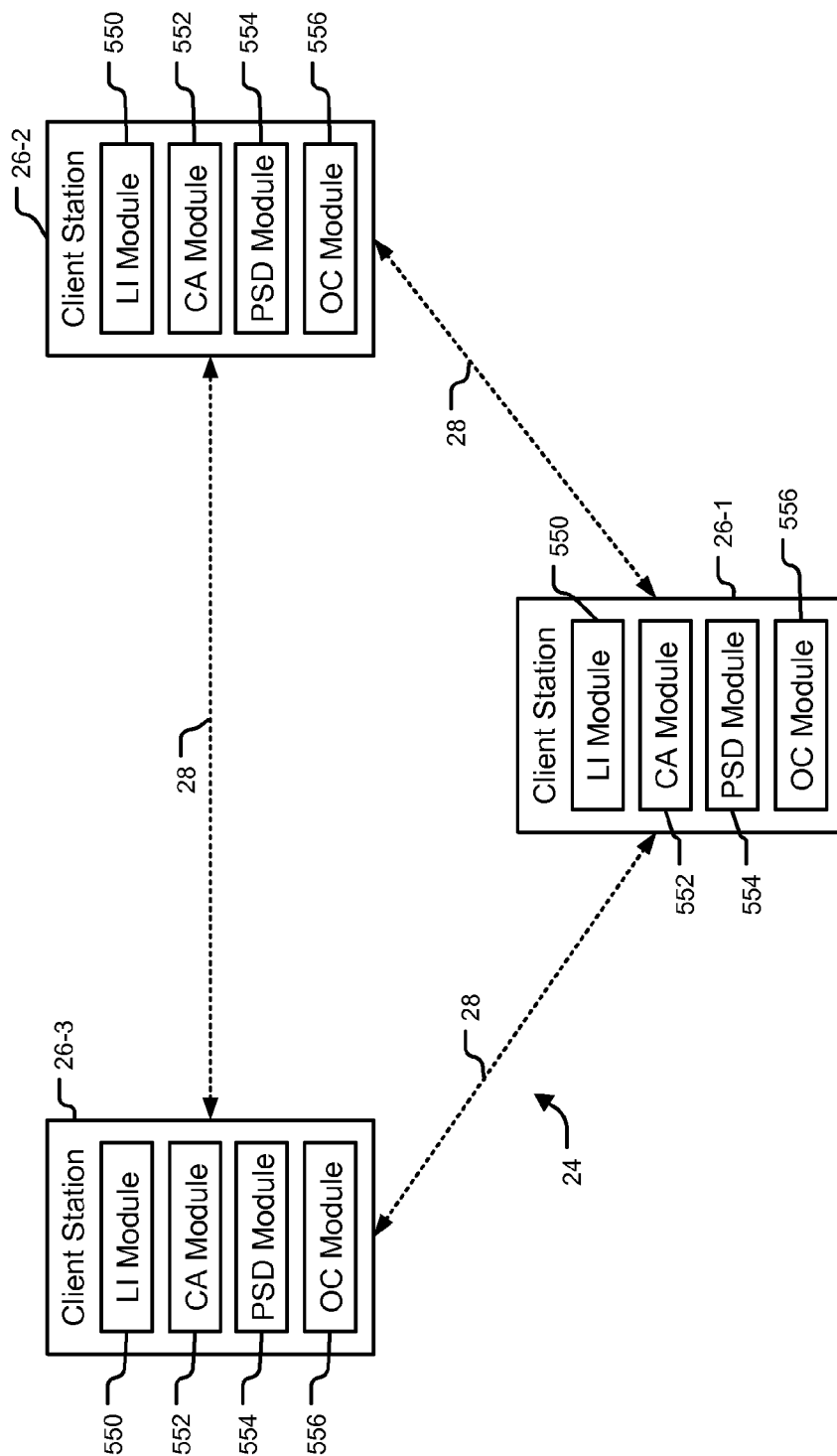


FIG. 20

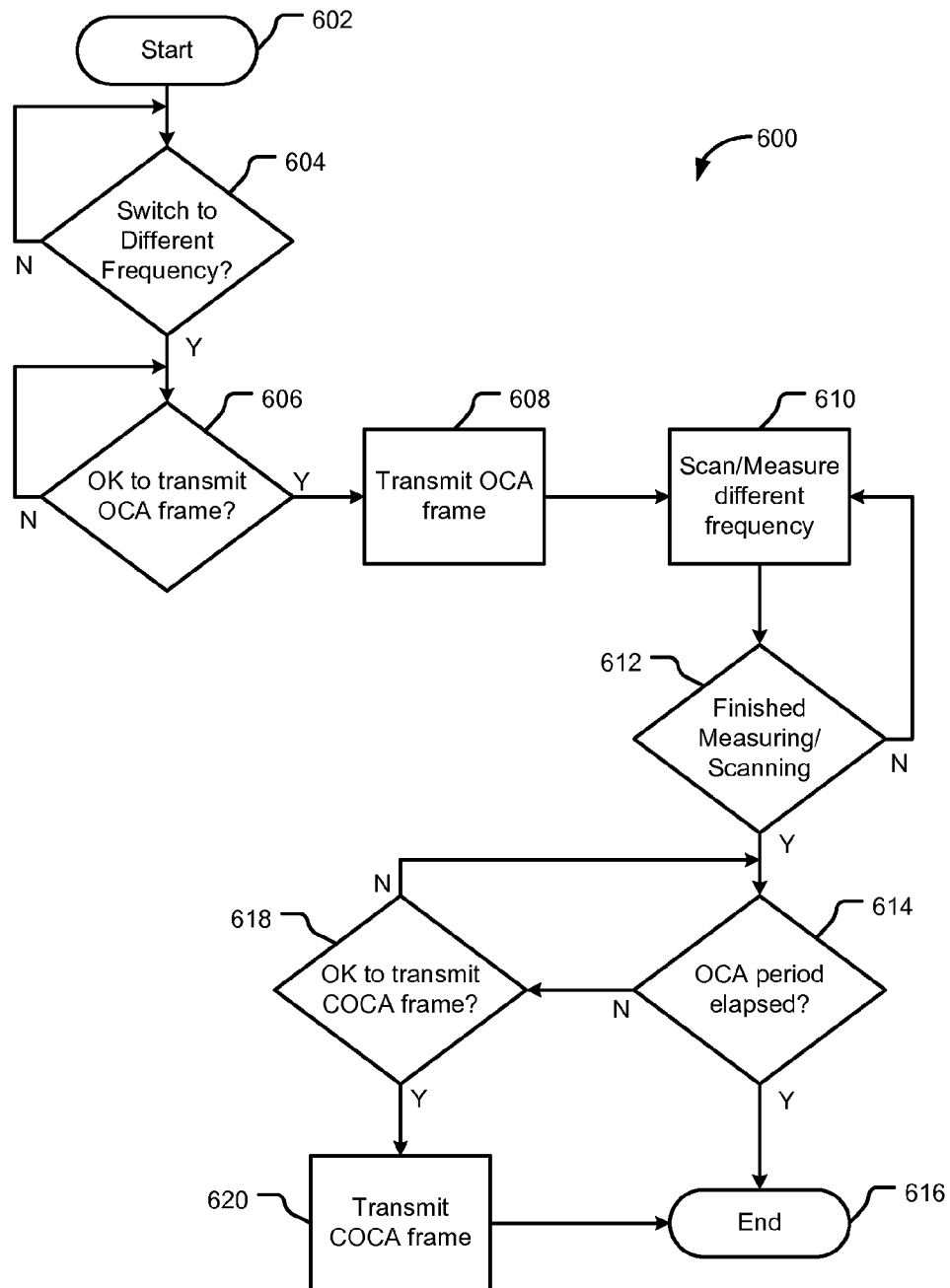


FIG. 21

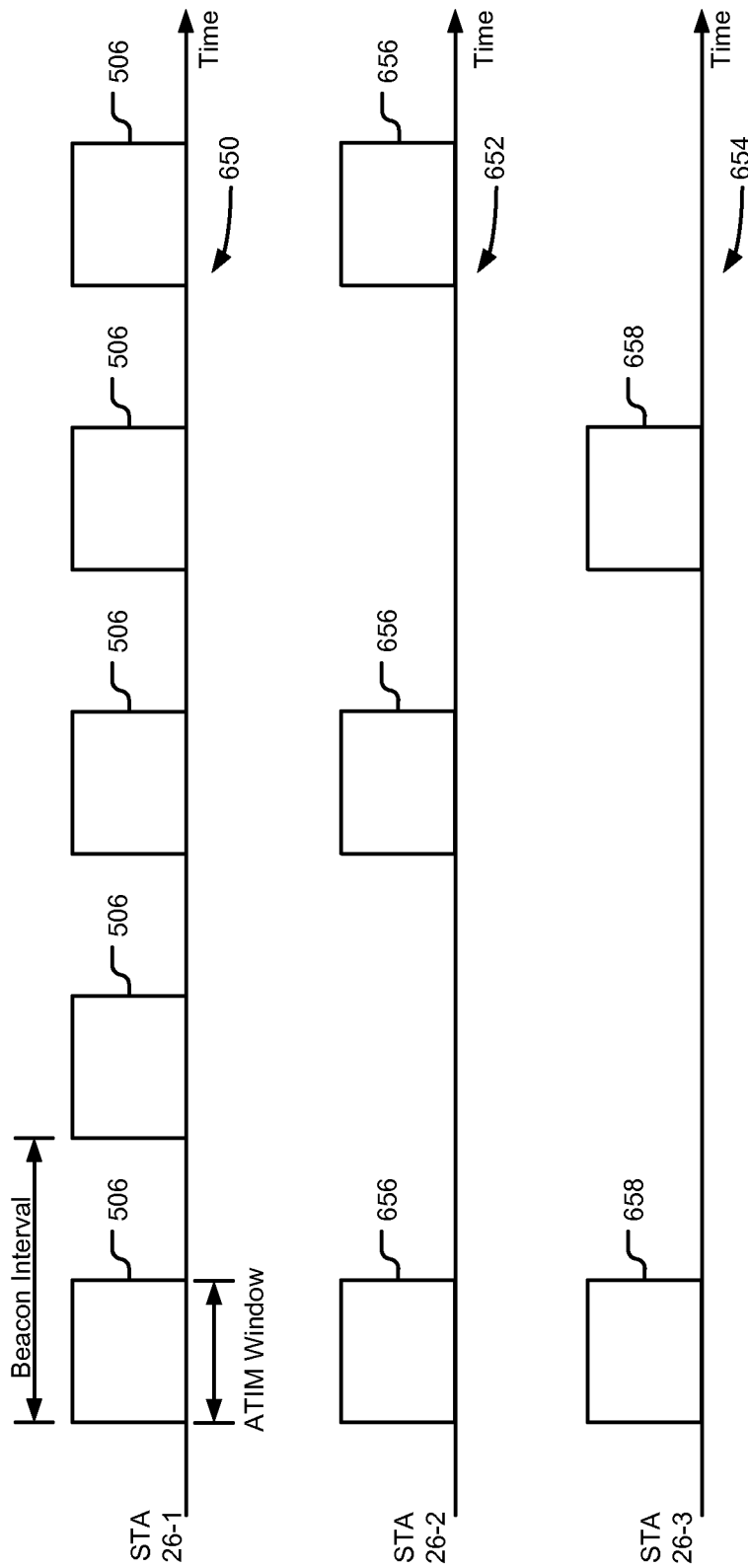


FIG. 22

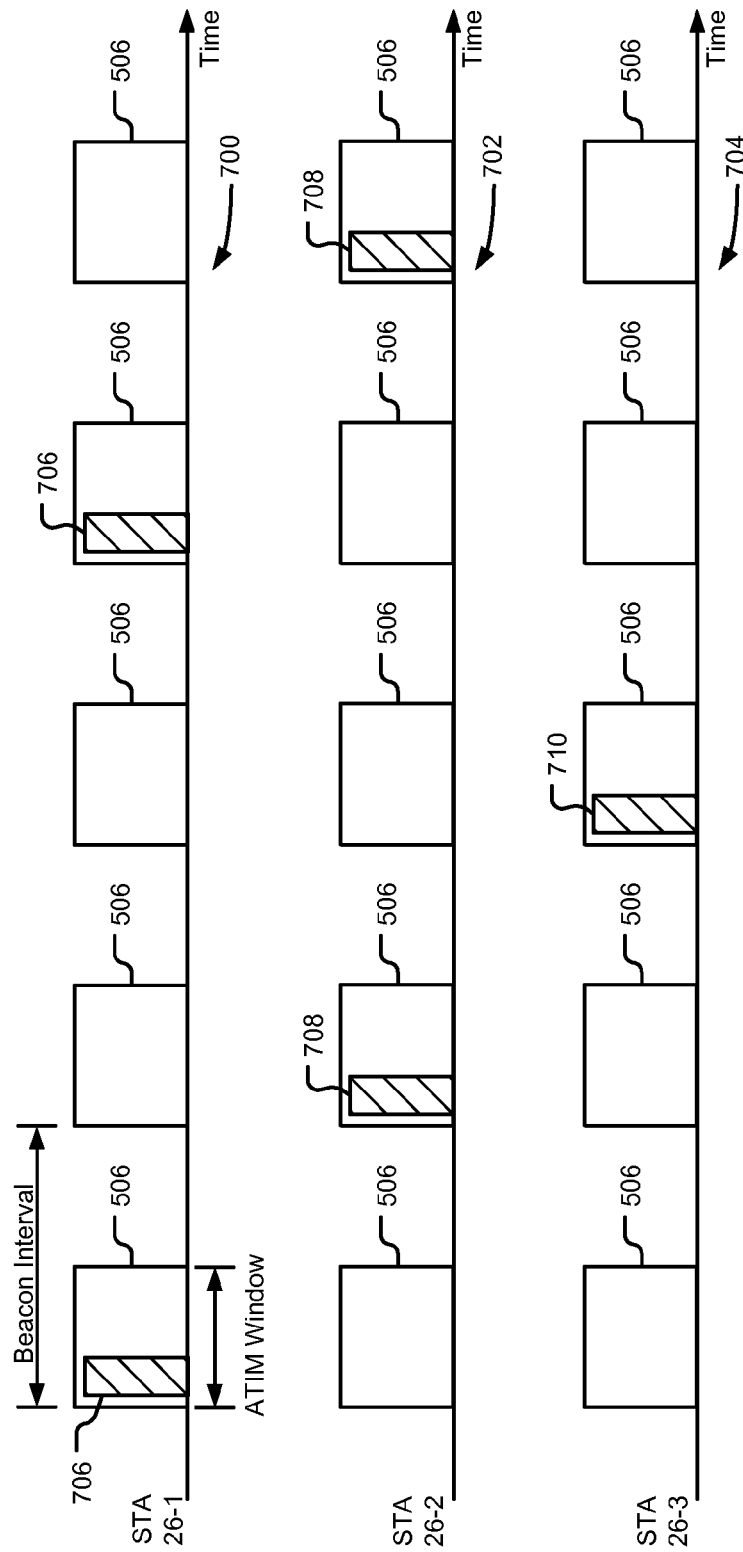


FIG. 23

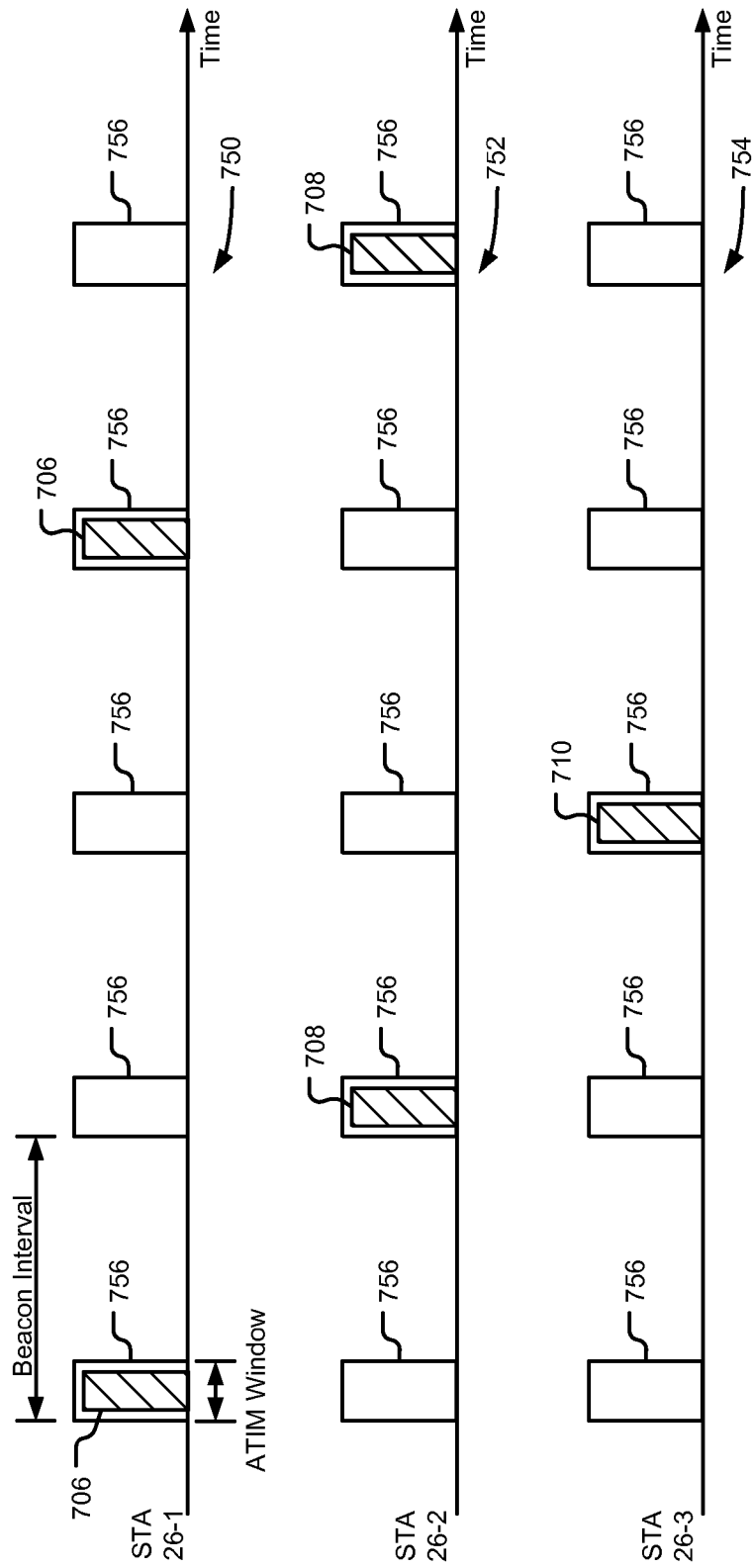


FIG. 24

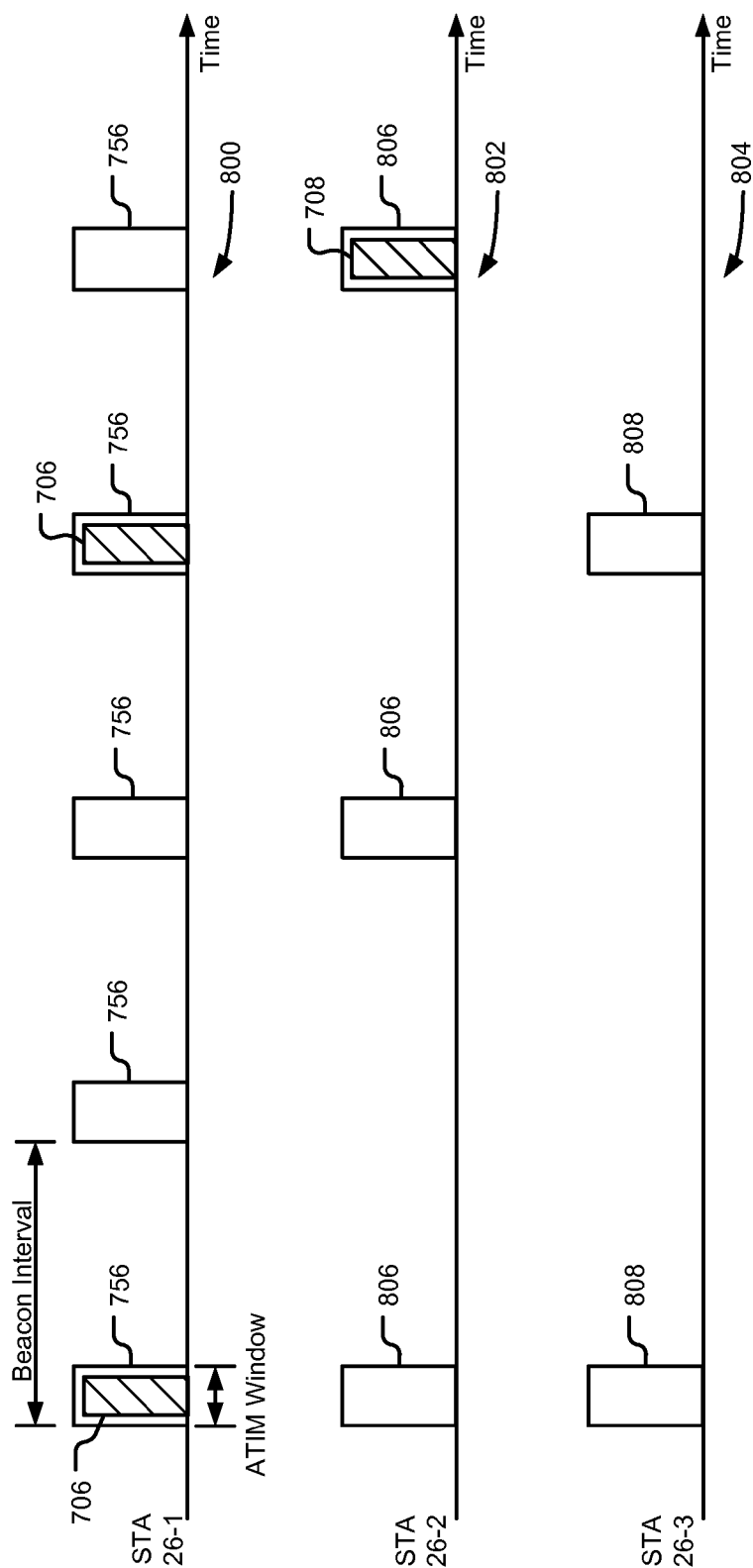


FIG. 25



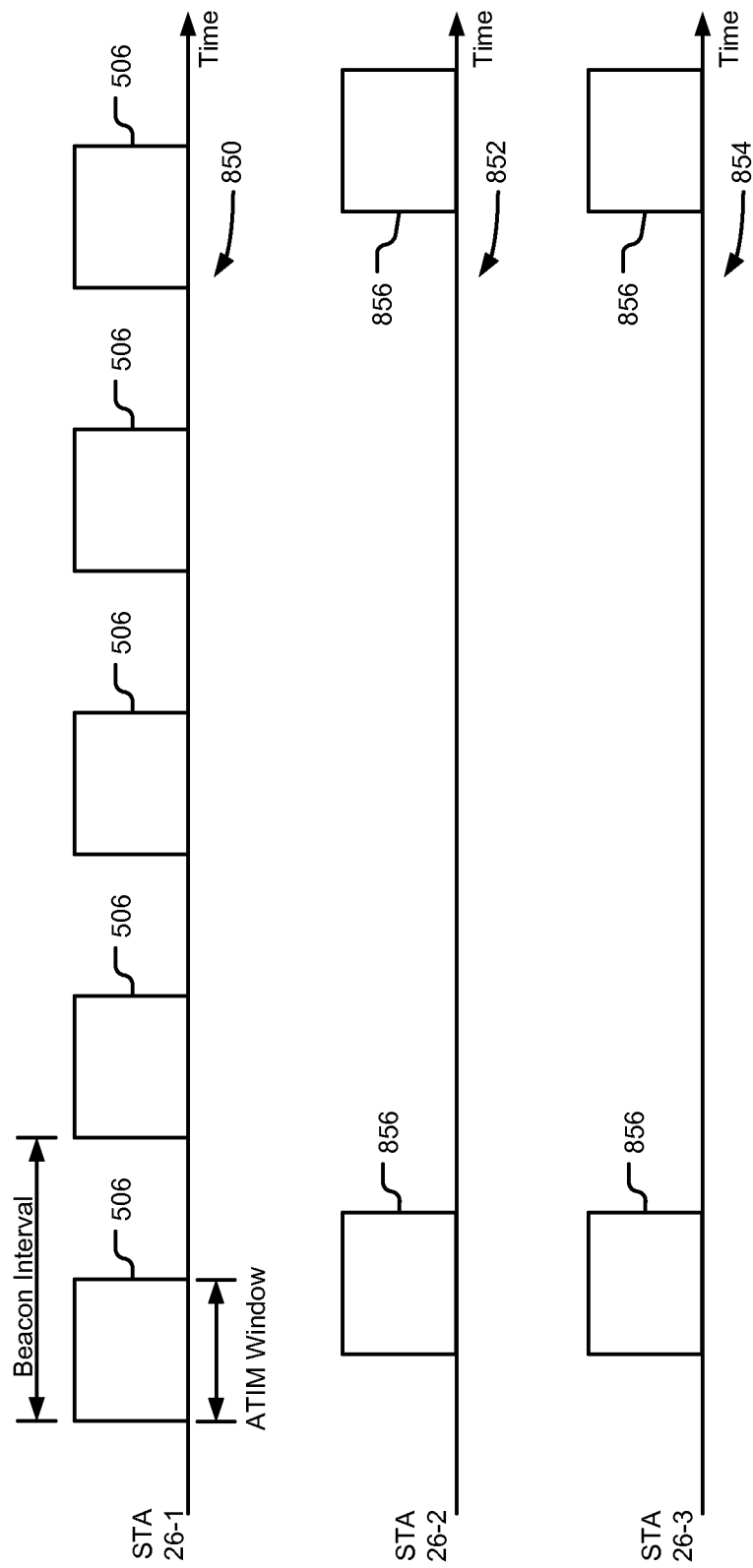


FIG. 26

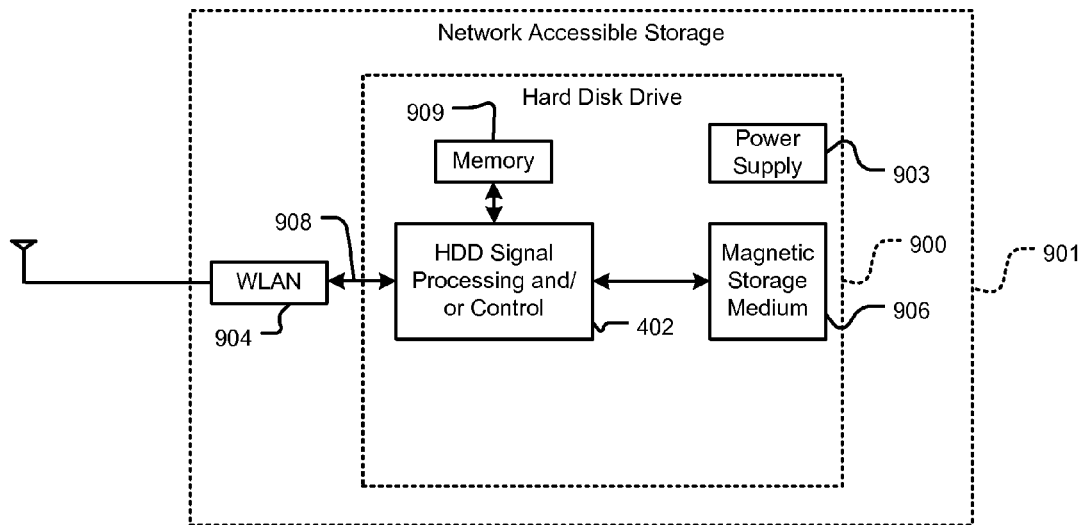


FIG. 27A

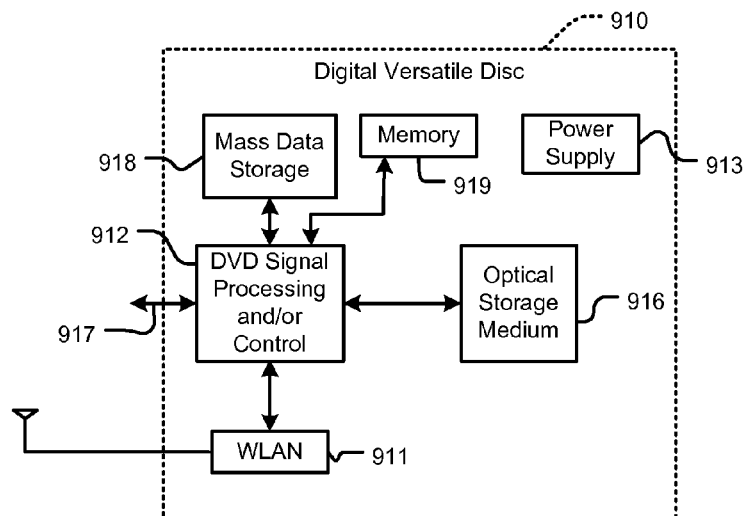
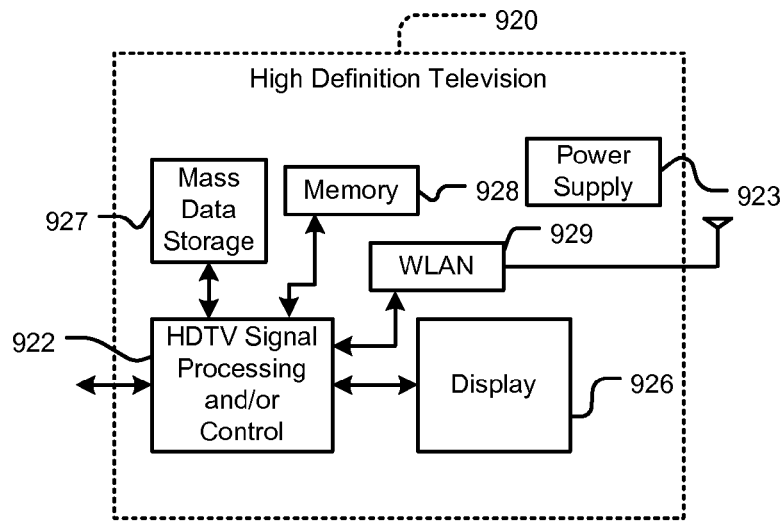
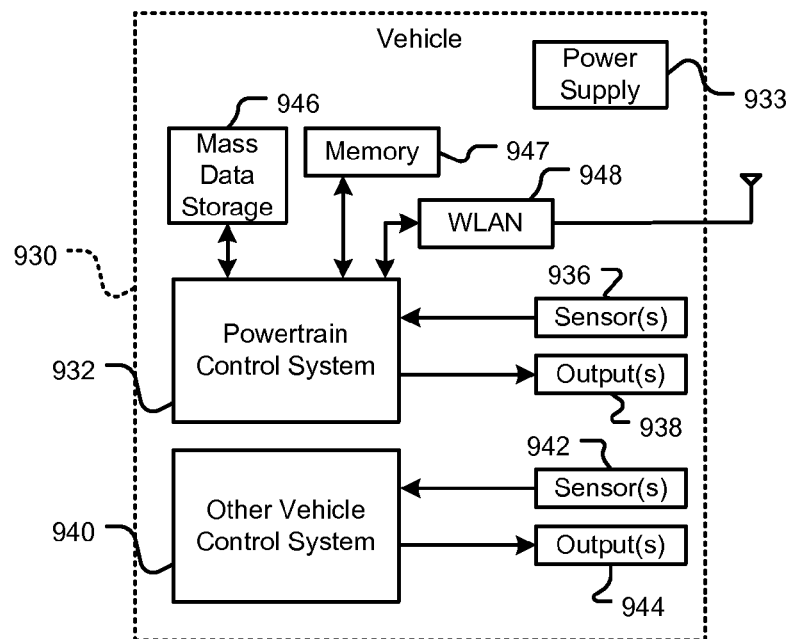


FIG. 27B

**FIG. 27C****FIG. 27D**

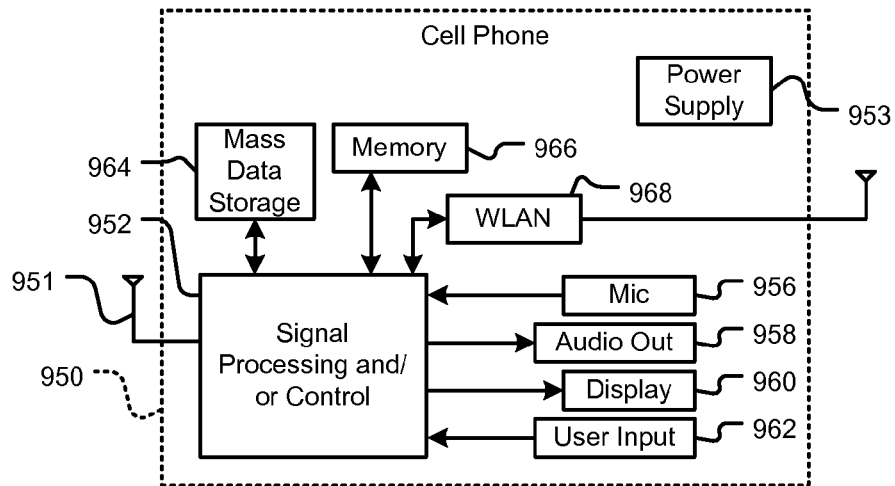


FIG. 27E

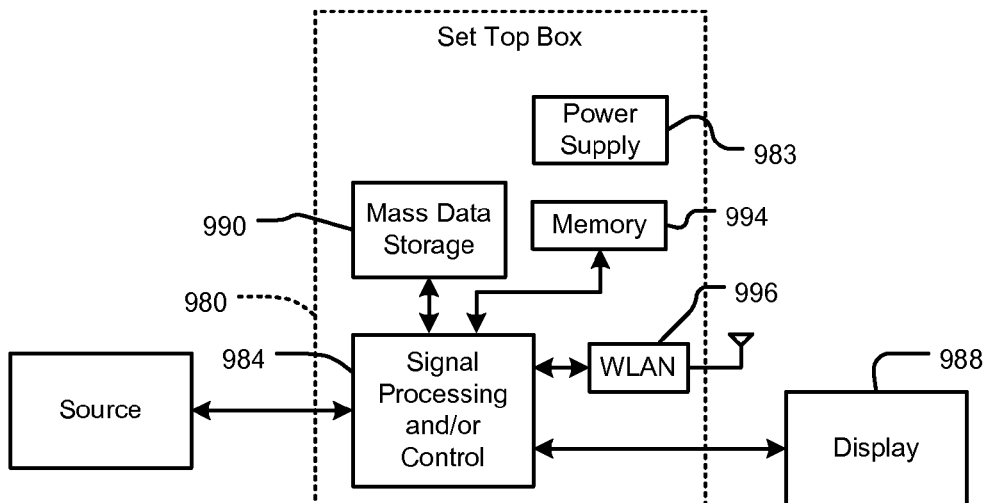
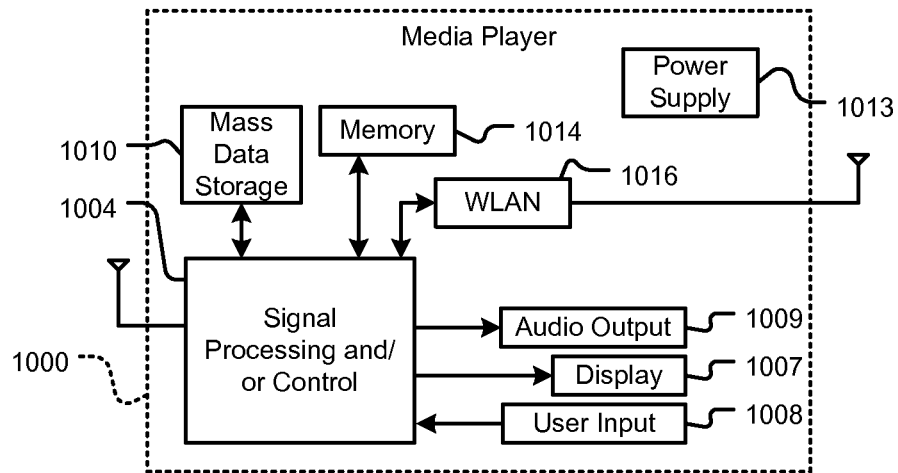


FIG. 27F

**FIG. 27G**

## WIRELESS LAN POWER SAVINGS

## CROSS-REFERENCE TO RELATED APPLICATIONS

This is a continuation of U.S. patent application Ser. No. 13/019,110, filed on Feb. 1, 2011, which is a continuation of U.S. application Ser. No. 11/351,232 (now U.S. Pat. No. 7,881,755), filed Feb. 9, 2006, which claims the benefit of U.S. Provisional Application No. 60/759,474, filed on Jan. 17, 2006, and U.S. Provisional Application No. 60/685,468, filed on May 26, 2005. The entire disclosures of the applications referenced above are incorporated herein by reference.

## TECHNICAL FIELD

The present invention relates to wireless networks, and more particularly to reducing power consumption of wireless network devices.

## BACKGROUND

IEEE defined several different standards for configuring wireless networks and devices. For example, 802.11, 802.11(a), 802.11(b), 802.11(g), 802.11(h), 802.11(n), 802.16, and 802.20. According to these standards, wireless network devices may be operated in either an infrastructure mode or an ad-hoc mode.

In the infrastructure mode, the wireless network devices or client stations communicate with each other through an access point. In the ad-hoc mode, the wireless network devices communicate directly with each other and do not employ an access point. The term client station or mobile station may not necessarily mean that a wireless network device is actually mobile. For example, a desktop computer that is not mobile may incorporate a wireless network device and operate as a mobile station or client station.

A wireless network that operates in the infrastructure mode includes an access point (AP) and at least one client station that communicates with the AP. Since the client stations are often battery powered, it is important to minimize power consumption to preserve battery life. Therefore, some client stations implement a low power mode and an active, or "awake," mode. During the active mode, the client station transmits and/or receives data. During the low power mode, the client station shuts down components and/or alters operation to conserve power. Usually, the client station is not able to transmit or receive data during the lower power mode.

A power management device controls and selects different operating modes of the client stations. During operation, the power management device instructs some of the modules to transition to a low power mode to conserve power. Additional information may be found in U.S. patent application Ser. No. 10/650,887, filed on Aug. 28, 2003, Ser. No. 10/665,252, filed on Sep. 19, 2003, and Ser. No. 11/070,481 filed on Mar. 2, 2005, which are hereby incorporated by reference in their entirety.

Referring now to FIG. 1, a first wireless network 10 is illustrated in an infrastructure mode. The first wireless network 10 includes one or more client stations 12 and one or more access points (AP) 14. The client station 12 and the AP 14 transmit and receive wireless signals 16. The AP 14 is a node in a network 18. The network 18 may be a local area network (LAN), a wide area network (WAN), or another network configuration. The network 18 may include other nodes such as a server 20 and may be connected to a distributed communications system 22 such as the Internet.

The client station 12 does not continuously transmit data to or receive data from the AP 14. Therefore, the client station 12 implements a power savings mode when the client station 12 and the AP 14 do not have data to exchange. Data commonly remains intact in a network for a predetermined amount of time before it is dropped. The client station 12 informs the AP 14 when the client station 12 is entering a low power mode (and will not be capable of receiving data for a predetermined period). After notifying the AP 14, the client station 12 transitions to the low power mode. During the low power period, the AP 14 buffers data in memory 15 that is intended to be transmitted to the client station 12. Following the low power period, the client station 12 powers up and receives beacon transmissions from the AP 14. If the beacon transmissions indicate that the AP 14 has data for the client station 12, or the host processor or the client station 12 indicates it has data to transmit, the client station 12 remains active. Otherwise, the client station 12 enters the low power mode again.

Before the AP 14 sends out a beacon transmission, the AP 14 determines whether other devices are currently transmitting data so that other devices are able to use the network. The AP 14 transmits a beacon at a target beacon transmission time (TBTT). The client station 12 transitions to the active mode prior to a beacon transmission to queue frames to transmit to the AP 14 in a buffer. Following a beacon transmission, the AP 14 may transmit multicast or broadcast frames to one or more client stations 12 in a deterministic order. To minimize collisions that may occur when one or more client stations 12 simultaneously attempt to transmit data to the AP 14, each station 12 may wait for a random delay prior to a transmission. The random delay, commonly referred to as backoff, reduces the chance of multiple station transmissions occurring simultaneously.

Referring now to FIG. 2, a second wireless network 24 operates in an ad-hoc mode. The second wireless network 24 includes multiple client stations 26-1, 26-2, and 26-3 that transmit and receive wireless signals 28. The client stations 26-1, 26-2, and 26-3 collectively form a LAN and communicate directly with each other. The client stations 26-1, 26-2, and 26-3 are not necessarily connected to another network. The client stations 26-1, 26-2, and 26-3 do not continuously transmit data to and receive data from each other. The client stations 26 implement a power savings mode when one of the client stations 26-1 does not have data to exchange with the other client stations 26-2 and 26-3.

The client stations 26-1, 26-2, and 26-3 periodically transition to the active mode prior to the TBTT and generate a random number. The client station with the smallest random number transmits the beacon to the other client stations. Following the beacon, the client stations 26-1, 26-2, 26-3 may transmit an announcement traffic indication messages (ATIM) frame during a predefined ATIM window to notify other client stations of any buffered data waiting at the client station. For example, if client station 26-1 has buffered data intended for station 26-2, station 26-1 will transmit an ATIM frame subsequent to the beacon to inform station 26-2 of the buffered data. Once station 26-2 acknowledges the ATIM frame, station 26-1 transmits the buffered data to station 26-2.

FIG. 3 depicts a typical system on chip (SOC) circuit 40 that can be used to implement a wireless Ethernet network device, that is, a client station and/or an AP. The SOC 40 generally includes one or more processors 42; a medium access controller (MAC) device 44; a base band processor (BBP) 46; and a host interface. Additionally, the SOC 40 may

include a radio frequency (RF) transceiver 48 or the transceiver may be located externally.

### SUMMARY

A system, comprising: a first receiver of a baseband processor (BBP) configured to determine whether a signal includes a frame; a second receiver of a media access controller (MAC) configured to identify a destination address in the frame; a processor configured to selectively process the frame; and a power management module configured to transition each of the first receiver of the BBP, the second receiver of the MAC, and the processor to the active mode based on predetermined criteria.

In yet other features, the systems and methods described above are implemented by a computer program executed by one or more processors. The computer program can reside on a computer readable medium such as but not limited to memory, non-volatile data storage and/or other suitable tangible storage mediums.

Further areas of applicability of the present invention will become apparent from the detailed description provided hereinafter. It should be understood that the detailed description and specific examples, while indicating the preferred embodiment of the invention, are intended for purposes of illustration only and are not intended to limit the scope of the invention.

### BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become more fully understood from the detailed description and the accompanying drawings, wherein:

FIG. 1 is functional block diagram of a wireless network operating in an infrastructure mode;

FIG. 2 is a function block diagram of a wireless network operating in an ad-hoc mode;

FIG. 3 is an exemplary system on a chip circuit that may be used to implement a wireless network device;

FIG. 4 is a functional block diagram of a wireless network device;

FIG. 5 is an exemplary graph depicting power consumption of the wireless network device;

FIG. 6 is a flowchart depicting exemplary steps to power-up the wireless network device according to the present invention;

FIG. 7 is an exemplary timing diagram for a client station operating in infrastructure mode according to the prior art;

FIG. 8 is an exemplary schematic of a beacon frame according to the prior art;

FIG. 9 is an exemplary timing diagram of a client station operating in infrastructure mode according to one embodiment of the present invention;

FIG. 10 is an exemplary schematic of a short beacon according to one embodiment of the present invention;

FIG. 11 is a functional block diagram of an exemplary network implementing short beacons according to one embodiment of the present invention;

FIG. 12 is a functional block diagram of an exemplary wireless network using a filter module according to one embodiment of the present invention;

FIG. 13A is an exemplary schematic of a beacon incorporating a multicast indication map frame according to one embodiment of the present invention;

FIG. 13B is an exemplary schematic of a short beacon incorporating a multicast indication map frame according to some embodiments of the present invention;

FIG. 14 is an exemplary flowchart that illustrates steps taken by the filter module according to one embodiment of the present invention;

FIG. 15 is an exemplary timing diagram an access point (AP) and two client stations operating in infrastructure mode wherein unicast data is transferred according to the prior art;

FIG. 16 is an exemplary timing diagram of an AP and two clients stations operating in infrastructure mode wherein unicast data is transferred according to one embodiment of the present invention;

FIG. 17 is an exemplary timing diagram of an AP and two client stations wherein multicast and broadcast data is transferred according to the prior art;

FIG. 18 is an exemplary timing diagram of an AP and two client stations wherein multicast and broadcast data is transferred according to one embodiment of the present invention;

FIG. 19 is an exemplary timing diagram of three client stations in ad-hoc mode according to the prior art;

FIG. 20 is a functional block diagram of three client stations utilizing a listen interval module, a contention avoidance module, a power save delivery module, and an off-channel module according to one embodiment of the present invention;

FIG. 21 is a flowchart illustrating exemplary steps taken by the off-channel module according to the present invention;

FIG. 22 is an exemplary timing diagram of three client stations in ad-hoc mode utilizing the listen interval module according to one embodiment of the present invention;

FIG. 23 is an exemplary timing diagram of three client stations in ad-hoc mode utilizing the contention avoidance module according to one embodiment of the present invention;

FIG. 24 is an exemplary timing diagram of three client stations in ad-hoc mode utilizing the contention avoidance module and a shortened announcement traffic indication message window according to one embodiment of the present invention;

FIG. 25 is an exemplary timing diagram of three client stations in ad-hoc mode utilizing the listen interval module and the contention avoidance module according to one embodiment of the present invention;

FIG. 26 is an exemplary timing diagram of three client stations in ad-hoc mode utilizing the power save delivery module according to one embodiment of the present invention;

FIG. 27A is an exemplary implementation of the present invention in a network accessed storage module;

FIG. 27B is an exemplary implementation of the present invention in a digital versatile disc drive;

FIG. 27C is an exemplary implementation of the present invention in a high definition television;

FIG. 27D is an exemplary implementation of the present invention in a wireless local area network device associated with a vehicle;

FIG. 27E is an exemplary implementation of the present invention in a cellular phone;

FIG. 27F is an exemplary implementation of the present invention in a set top box; and

FIG. 27G is an exemplary implementation of the present invention in a media player.

### DETAILED DESCRIPTION

The following description of the preferred embodiment(s) is merely exemplary in nature and is in no way intended to limit the invention, its application, or uses. For purposes of clarity, the same reference numbers will be used in the draw-

5

ings to identify similar elements. As used herein, the term module, circuit and/or device refers to an Application Specific Integrated Circuit (ASIC), an electronic circuit, a processor (shared, dedicated, or group) and memory that execute one or more software or firmware programs, a combinational logic circuit, and/or other suitable components that provide the described functionality. As used herein, the phrase at least one of A, B, and C should be construed to mean a logical (A or B or C), using a non-exclusive logical or. It should be understood that steps within a method may be executed in different order without altering the principles of the present invention.

Each client station 12, 26-1, 26-2, 26-3 includes a wireless network device 60 as shown in FIG. 4. The wireless network device 60 may include an RF transceiver module 62, a base-band processor (BBP) module 64, a media access control (MAC) module 68, a power management module 69, and a processor 70 that communicates with a host 71. The RF transceiver 62 includes a receiver 72 and a transmitter 74.

During receiver operation, an input of a low noise amplifier (LNA) 84 receives signals from an antenna 85, amplifies the signals and outputs them to the receiver 72. During transmitter operation, an output of the transmitter 74 is received by a power amplifier (PA) 86, which outputs amplified signals to the antenna 85.

On the receiver side, the BBP module 64 includes an analog to digital converter (ADC) 88 that receives in-phase (I) and quadrature (Q) signals from the receiver 72. The ADC 88 communicates with a demodulator 90, which demodulates the signals. The ADC 88 and the demodulator 90 may generally be referred to as a physical receiver (PHY Rx) 91. However, when the RF transceiver 62 is incorporated in the network device 60, the PHY Rx 91 may also include the receiver 72 and the LNA 84. An output of the demodulator 90 communicates with an external interface 92, which communicates with a MAC receiver (MAC Rx) 93. A MAC transmitter (MAC Tx) 94 sends signals to the external interface 92, which are modulated by a modulator 95 and output to a digital to analog converter (DAC) 96. Both the MAC Tx 94 and MAC Rx 93 may each be a state machine that controls transmission and reception of data. The DAC 96 outputs I and Q signals to the transmitter 74. The modulator 95 and the DAC 96 may generally be referred to as a physical transmitter (PHY Tx) 97. However, when the RF transceiver 62 is incorporated in the network device 60, the PHY Tx 97 may also include the transmitter 74 and the PA 86.

The power management module 69 along with the MAC module 68 and processor 70 selects an operating mode of the wireless network device 60. The operating modes include active and inactive (i.e. low power) modes, although additional modes may be provided. In the active mode, the wireless network device is completely powered up and is fully functional. In some embodiments when the wireless network device is operating in the inactive mode, no power is supplied to the component or a sufficient amount of power is supplied to maintain logic states but not full operation. As a result, the wireless network device dissipates less power when operating in the inactive mode than in the active mode. The power management module 69 may also be located in the MAC module 68.

Referring now to FIG. 5, an exemplary graph depicting power consumption of the network device 60 versus time is illustrated. The dashed line 102 represents the power consumed for a network device powered up in a conventional manner. However, in a multistage power-up sequence according to the present invention, the power management module 69 only activates necessary components of the network

6

device 60. As shown, the power management module 69 activates the RF transceiver 62 in anticipation of receiving a beacon from the AP 14 at 104. If the RF transceiver 62 receives a signal with an energy greater than a predetermined energy threshold, the power management module 69 may activate the PHY Rx 91 at 106. However, if the energy of the signal is less than the predetermined energy threshold, the power management module 69 may deactivate the RF transceiver 62 at 108.

If the PHY Rx 91 determines that the signal received by the RF transceiver 62 is a frame containing a valid preamble, the power management module 69 may activate the MAC Rx 94 at 110. However, if the signal is not a frame containing a valid preamble, the power management module 69 may deactivate the PHY Rx 91 and the RF transceiver 62 at 112. The MAC Rx 93 determines whether the frame has a valid payload. For example, the payload may be valid if it contains a destination address corresponding to the network device. If the frame has a valid payload, the power management module 69 may activate the processor at 114. However, if the frame does not contain a valid payload, the power management module 69 may deactivate the MAC Rx 94, the PHY Rx 91, and the RF transceiver 62 at 116.

The processor 70 receives the frame and delivers it to the host 71. If the processor 70 and/or host 71 determines that a response is required, the power management module 69 may activate the MAC Tx 94 at 118 and the PHY Tx 97 at 120. Once the response has been sent, the power management module 69 may deactivate the network device at 122. If a response is not required, the power management module 69 may deactivate the processor 70, the MAC Rx 93, the PHY Rx 91, and the RF transceiver 62 at 124.

As previously discussed, when the network device 60 includes the RF transceiver 62, the PHY Rx 91 also includes the receiver 72 and LNA 84. In addition, the PHY Tx 97 also includes the transmitter 74 and the PA 86. Using the multistage power-up sequence according to the present invention, the receiver 72 and the LNA 84 may be activated in anticipation of receiving a beacon at 104 rather than activating the entire RF transceiver 62. In addition, the transmitter 74 and PA 86 may be powered up when the processor 70 and/or host 71 determines that a response is required.

As shown, the multistage power-up sequence of the present invention minimizes the amount of power consumed by the network device 60. More specifically, the area identified at 126 generally represents the amount of power savings the multistage power-up sequence may have over powering up the network device 60 in a conventional manner.

Referring now to FIG. 6, the multistage power-up sequence may implement steps generally identified at 150. The power-up sequence starts at 152. The power management module 69 anticipates a beacon from the AP 14 by monitoring the TBTT in step 154. If the power management module 69 determines that the TBTT is not approaching, the process returns to step 152. If the TBTT is approaching, the power management module 69 activates the RF transceiver 62 in step 156. In step 158, the RF transceiver 62 determines whether the energy of the signal received is greater than the predetermined energy threshold. If the energy of the signal is not greater than the predetermined energy threshold, the power management module 69 determines whether to sense the energy of the signal again in step 159. If the power management module 69 determines to sense the energy of the signal again, the process returns to step 158. If the power management module 69 determines not to sense the energy again, the power management module 69 may wait for a predetermined time in step



160 and then deactivate the RF transceiver 62 in step 161. The process returns to step 154 for the next beacon.

If the RF transceiver 62 determines that the energy of the signal is greater than the predetermined threshold in step 158, the power management module 69 may activate the PHY Rx 91 in step 164. In step 166, the PHY Rx 91 determines whether the signal contains a frame with a valid preamble. If the signal does not contain a frame with a valid preamble, the power management module 69 may wait for a predetermined time in step 167 and then deactivate the PHY Rx 91 in step 168.

If the PHY Rx 91 determines that the signal contains a frame with a valid preamble in step 166, the power management module 69 may activate the MAC Rx 93 in step 170. The MAC Rx 93 determines whether the frame contains a valid payload in step 172. If the frame does not contain a valid preamble, the power management module 69 may wait for a predetermined time in step 173 and deactivate the MAC Rx 93 in step 174.

If the PHY Rx 91 determines that the frame contains a valid payload in step 172, the power management module 69 may activate the processor 70 in step 176. The processor 70 may communicate the frame to the host 71 as previously discussed. In step 178, the processor 70 and/or the host 71 determines whether a response is required. If a response is not required, the power management module 69 may wait for a predetermined time in step 179 and then deactivate the processor 70 in step 180.

If the processor 70 and/or host 71 determines that a response is required, the power management module 69 may activate the MAC Tx 94 in step 182 and the PHY Tx 97 in step 184. In step 186, the processor 70 and/or host 71 sends the required response. Once the response has been sent, the power management module 69 may wait for a predetermined time in step 187 and then deactivate the PHY Tx 97 in step 188. Once the PHY Tx 97 is deactivated, the power management module 69 may wait for a predetermined period in step 189 and then deactivate the MAC Tx 94 in step 190.

In some embodiments, it may be desirable for the components of the network device 60 to active and/or deactivate without waiting for a predetermined period. Thus, it may be desirable to set the predetermined periods discussed with respect to steps 160, 167, 173, 179, 187, and 189 to zero.

Referring to now FIG. 7, an exemplary timing diagram 200 according to the prior art is illustrated. One or more client stations 12 enter the active mode prior to the transmission of a beacon signal 202 that is periodically transmitted by the AP 14. The beacon signal 202 broadcasts information to the client stations 12 informing them that data is buffered at the AP 14. The client stations 12 stay awake for the entire beacon signal as shown at 204. To help conserve power, each client station 12 may have an associated listen interval. The listen interval represents how long a client station sleeps before waking up to listen to the beacon signal 202. For example, if the listen interval is 1 a client station wakes up for every beacon signal and if the listen interval is 2 a client station wakes up for every other beacon signal. In FIG. 7 the client station 12 has a listen interval of 2, therefore the client station 12 wakes up for every other beacon signal. If the client station 12 has data buffered at the AP 14, it may enter the active mode to retrieve the data from the AP 14.

Referring now to FIG. 8, the beacon signal 202 includes a header field 210, a timestamp field 212, a traffic indication map (TIM) field 214, and other miscellaneous fields 216. The header field 210 is at the beginning of the beacon signal 202 and contains information informing a client station how to handle the remaining data. The timestamp field 212 is used by

the client stations 12 to update a timing synchronization function (TSF) associated with each station. The TSF is updated to ensure that the timing of each client station 12 is synchronized. The TIM field 214 contains information to inform the client stations 12 that the AP 14 has buffered data waiting. The miscellaneous fields 216 may contain data to allow client stations that are not connected to the network 10 to find and connect to the network 10. However, client stations that are already connected to the network generally do not need the information contained in the miscellaneous fields 216.

Referring now to FIG. 9, an exemplary timing diagram 220 according to one embodiment of the present invention is illustrated. The client stations 12 that are already connected to the network 10 may receive a short beacon signal 222 in place of the beacon signal 202. The short beacon signal 222 contains information for the client stations 12 that are already connected to the network 10. When the AP 14 transmits the short beacon signal 222, the connected client stations 12 need to stay awake for a shortened time as shown at 224. The AP 14 may also transmit the longer or standard beacon 202 for prior art clients that are not compatible with the short beacon signal 222 and/or for any client stations that wish to join the network 10.

Referring now to FIG. 10, the short beacon signal 222 is illustrated. The short beacon signal 222 only contains fields that are required by the client stations 12 that are already connected to the network 10. The fields include the header field 210, the timestamp field 212, and the TIM field 214. As previously discussed, the header field 210 informs the client stations 12 how to handle the remaining data. The timestamp field 212 is used synchronize timing of the client stations 12 connected to the network 10. The TIM field 214 informs the client stations 12 that the AP 14 has buffered data waiting for them. The short beacon signal 222 is offset from the beacon signal 202 so that transmission of the short beacon signal 222 is complete before the TBTT. Since transmission of the short beacon signal 222 is complete before the TBTT, the AP 14 may transmit the standard beacon 202 at the TBTT for prior art clients that are unaware of the short beacon signal 222.

Referring now to FIG. 11, a beacon control module 228 may be incorporated in the AP 14 as shown. The beacon control module 228 may control transmission of the standard beacon signal 202 and the short beacon signal 222 as described above. The beacon control module 228 may also communicate with a link connection module 229 that establishes and maintains a link between the AP 14 and the client station 12 based on data in the standard beacon signal 202. Once the link has been established, the client station 12 may wake up for the short beacon 222 rather than the standard beacon 202.

Referring now to FIG. 12, a filter module 230 may be incorporated in the AP 14 as shown. When the client station 12 is in the power save mode it may only have an interest in certain types of data. The client station 12 periodically wakes up to receive a beacon sent from the AP 14. If the beacon indicates that data is buffered at the AP 14, the client station 12 sends a power save poll (PS-Poll) frame to the AP 14 requesting the data. When the AP 14 receives the PS-Poll frame, the AP 14 sends the buffered data to the client station 12. Once the client station 12 receives the data, it applies filters to determine if the data is of any significance to the client station 12. The operation of requesting and receiving the buffered data requires the client station 12 to stay awake and consequently consumes additional power. The filter module 230 allows the AP 14 to reduce the amount of power consumed by the client station 12 by filtering unwanted data on behalf of the client station 12.

The client station 12 may include a client filter module 231 that generates a filter parameter, which is transmitted to the AP 14, indicating specific types of data that the client station 12 wishes to receive. More specifically, the client station 12 may have an interest in certain types of unicast and/or multi-  
 5 cast data. Therefore, the filter module 230 may include a unicast filter 232 and a multicast filter 234. The unicast filter 232 may be configured by the client station 12 to allow certain types of unicast transmissions. Some criteria that may be used to configure the unicast filter 232 include, but are not limited to, a source MAC address, a priority of data, a source address and/or port, a destination address and/or port, and a protocol type. When the unicast data matches the unicast filter 232, the AP 14 may set a bit in the TIM field 214 to notify the client station 12 of the buffered unicast data. If the unicast data does  
 15 not match the unicast filter 232, the AP 14 may discard the data.

The multicast filter 234 works in a similar manner as the unicast filter 232. However, the AP 14 uses the multicast filter 234 to filter multicast and/or broadcast data. To support the  
 20 multicast filter 234 a Multicast Traffic Indication Map (MTIM) frame 240 may be incorporated in the beacon 202 as shown in FIG. 13A. The MTIM frame 240 contains a bit for each client station that instantiates the multicast filter 234 to filter broadcast and/or multicast traffic. The bit corresponding  
 25 to a client station is set when buffered broadcast and/or multicast traffic matches the multicast filter 234. In addition, the MTIM frame 240 may be used with the short beacon 222 as shown in FIG. 13B.

There may be certain types of data that the client station 12  
 30 always responds to in the same manner. Therefore, the client station 12 may remotely configure a proxy filter module 242 as shown in FIG. 12 to respond to certain types of data on its behalf. For example, a remote client may wish to contact the client station 12. The remote station may send an address  
 35 resolution protocol (ARP) request with an IP address associated with the client station 12. An ARP request is typically used to determine a MAC address of a client station. Rather than waking the client station 12 to respond to the ARP request, the AP 14 may use the proxy filter module 242  
 40 to respond to the ARP request on its behalf. Although an ARP request is described herein for illustrative purposes, the proxy filter module 242 may be configured to respond to any type of data on behalf of the client station 12.

Referring now to FIG. 14, the filter module 230 may implement steps generally identified at 250 to filter data on behalf  
 45 of the client station 12. The process begins in step 252 when the AP 14 receives data that is intended for the client station 12. In step 254, the filter module 230 determines whether the data matches the proxy filter module 242. If the data matches  
 50 the proxy filter module 242, the AP 14 sends a predetermined response on behalf of the client station 12 in step 256 and the process ends in step 258.

If the data does not match the proxy filter module 242 in  
 55 step 254, the filter module 230 determines whether the data matches the unicast filter 232 in step 260. If the data matches the unicast filter 232, the AP 14 sets the TIM bit for the corresponding client station 12 in step 262 and the process ends in step 258.

If the data does not match the unicast filter 232 in step 260,  
 60 the filter module 230 determines whether the data matches the multicast filter 234 in step 264. If the data matches the multicast filter 234, the AP 14 sets the MTIM bit corresponding with the client station 12 in step 266 and the process ends in step 258.

Referring now to FIG. 15, exemplary timing diagrams of a unicast transmission from an AP to two client stations that are

in power save mode are illustrated at 270, 272, and 274. Every  
 beacon interval, the AP 14 transmits a beacon frame with the  
 TIM field 214. Station 1 has a listen interval of 2 and wakes up  
 every other beacon frame. Station 2 has a listen interval of 3  
 5 and wakes up every third beacon frame.

A first beacon frame 276 is transmitted indicating that there  
 are frames buffered for station 1. Station 2 wakes up to inspect  
 the first beacon frame 276 at 278. Since there are no frames  
 buffered for station 2, it can return to sleep. A second beacon  
 10 frame 280 is transmitted indicating that there are buffered  
 frames for station 1 and station 2. Station 1 wakes up at 282 to  
 listen to the second beacon frame 280. Station 1 sends a PS-Poll  
 frame to the AP 14 to retrieve the buffered frame for  
 station 1 at 284. At 286, the AP 14 sends the buffered frame to  
 15 station 1. Once station 1 receives the buffered frame, it may  
 return to sleep. A third beacon frame 288 is transmitted indi-  
 cating that there are buffered frames for station 1 and station  
 2. However, due to the respective listen intervals of stations 1  
 and 2, neither station wakes up to inspect the third beacon  
 20 frame 288.

A fourth beacon frame 290 is transmitted indicating that  
 there are still buffered frames for station 1 and station 2. Both  
 stations wake up as shown at 292 and 294 to receive the fourth  
 beacon frame 290. Since there are frames for both stations,  
 each station must wait for its turn to transmit a PS-Poll frame.  
 The stations randomly select a slot within a contention win-  
 25 dow to prevent them from transmitting at the same time.  
 Station 1 has a shorter random delay and transmits a PS-Poll  
 frame at 296. At 298, the AP 14 transmits the buffered frame  
 to station 1. Once station 1 receives the frame, it can return to  
 sleep and station 2 may transmit a PS-Poll frame at 300. At  
 302, the AP 14 transmits the buffered frame to station 2. Once  
 station 2 receives the buffered frame, it can return to sleep.

A fifth beacon frame 304 is transmitted, however neither  
 35 station wakes up to receive it due to the respective listen  
 intervals. A sixth beacon frame 306 is transmitted without any  
 frames buffered at the AP 14. Station 1 wakes up at 308 to  
 receive the sixth beacon and subsequently goes back to sleep.

Referring now to FIG. 16, an exemplary timing diagram of  
 40 unicast traffic is illustrated at 330, 332, 334 wherein the AP 14  
 uses the unicast filter 232 to filter data on behalf of station 1  
 and station 2. Station 1 has configured the unicast filter 232 to  
 filter out any frames that do not have a specific protocol  
 identification. The AP 14 receives frames for station 1 that do  
 not match the unicast filter 232. Therefore, a first beacon  
 frame 336 is transmitted without indicating that there are  
 buffered frames for station 1. Station 2 wakes up to inspect the  
 first beacon frame at 338. Since there are no buffered frames  
 for station 2, it can return to sleep. A second beacon frame 340  
 50 is transmitted and station 1 wakes up to inspect the beacon at  
 342. Station 1 subsequently goes back to sleep since the AP  
 14 has filtered the traffic on behalf of station 1. The AP 14  
 receives frames for station 1 and station 2. However, the  
 frames for station 1 do not match the unicast filter 232. There-  
 fore, the AP 14 transmits a third beacon frame 344 indicating  
 that there are only buffered frames for station 2. However due  
 to the listen intervals, station 1 and station 2 remain asleep.

The AP 14 receives frames for station 1 and station 2. The  
 frame for station 1 does not match the unicast filter 232 and is  
 discarded by the AP 14. A fourth beacon frame 346 is trans-  
 mitted indicating that there are buffered frames for station 2.  
 Both stations wake up as shown 348 and 350 to receive the  
 fourth beacon frame 346. Station 1 goes back to sleep after the  
 fourth beacon frame 346 since the AP 14 has filtered the  
 65 undesired frame on its behalf. Station 2 sends a PS-Poll frame  
 to the AP 14 at 352. The AP 14 sends the buffered frame to  
 station 2 at 354 and station 2 subsequently goes back to sleep.

11

A fifth beacon 356 is transmitted but neither station wake up due to the respective listen intervals. A sixth beacon 358 is transmitted and station 1 wakes up at 360. Since the AP 14 does not have buffered frames for station 1, it can go back to sleep when the sixth beacon frame 360 ends. As shown in FIG. 16, station 1 and station 2 can sleep longer when the AP 14 uses the unicast filter 232 to filter unicast frames on behalf of the stations.

Referring now to FIG. 17 exemplary timing diagrams of multicast and/or broadcast transmissions from the AP 14 to two client stations that are in power save mode are illustrated at 400, 402, and 404. When multicast and/or broadcast frames are received, the AP 14 buffers the frames in a similar manner as the unicast frames. The frames are buffered whenever any station associated with the AP 14 is sleeping. The AP 14 indicates whether any broadcast or multicast data frames are buffered by setting the first bit in the TIM frame 214. Beacons are periodically broadcast that contain the TIM frame 214. At a fixed number of beacon intervals, a Delivery Traffic Indication Map (DTIM) frame is sent. Buffered broadcast and multicast frames are transmitted after a beacon containing the DTIM frame has been transmitted by the AP 14.

In FIG. 17 the DTIM interval is set to 2, therefore every other beacon contains the DTIM frame. Station 1 and station 2 are operating in the power save mode and have a listen interval of 2 and 3, respectively. A first beacon frame 406 is transmitted that only contains the TIM frame. Station 1 remains asleep due to its listen interval. However, station 2 wakes up at 408 to listen to the first beacon frame 406 and subsequently goes back to sleep. A second beacon frame 410 is transmitted that contains the DTIM frame and the first bit of the TIM frame 214 is set indicating that broadcast and/or multicast frames are buffered at the AP 14. Station 1 wakes up to receive the second beacon 410 at 412. The AP 14 transmits the buffered broadcast frame at 414 and the buffered multicast frame at 416. Once station 1 receives the buffered multicast frame it may return to sleep.

A third beacon 418 is transmitted that only contains the TIM frame 214. However, neither station wakes up due to the respective listen intervals. A fourth beacon frame 420 that contains the DTIM frame is transmitted. The first TIM bit is set in the fourth beacon frame 420 indicating that the AP 14 has buffered broadcast and/or multicast frames. Station 1 wakes up at 422 and station 2 wakes up at 424. The AP 14 transmits the buffered broadcast frame at 426 and the buffered multicast frame at 428. When station 1 and station 2 receive the buffered multicast frame, they can both return to sleep. A fifth beacon 430 that only contains the TIM frame 214 is transmitted. However, station 1 and station 2 remain asleep due to the respective sleep intervals.

Referring now to FIG. 18, exemplary timing diagrams 450, 452, 454 of unicast data are illustrated wherein the AP 14 uses the multicast filter 234 to filter data on behalf of station 1 and station 2. The DTIM interval is set to 2, therefore every other beacon contains the DTIM frame. In addition, station 1 and station 2 are operating in the power save mode. Before entering the power save mode, station 1 notified the AP 14 that it is not interested in any broadcast or multicast data. Station 2 did not configure the multicast filter 234 before entering the power save mode. Station 1 has a listen interval of 2 and station 2 has a listen interval of 3.

A first beacon frame 456 is transmitted that only contains the TIM frame 214. Station 1 remains asleep due to its listen interval. However, station 2 wakes up at 458 to listen to the first beacon frame 456 and subsequently goes back to sleep. A second beacon frame 460 is transmitted that contains the DTIM frame and the first bit of the TIM frame 214 is set

12

indicating that broadcast and/or multicast data is buffered at the AP 14. However, the MTIM bit associated with station 1 has not been set because station 1 is not interested in broadcast or multicast data. Station 1 wakes up at 462 to receive the second beacon frame 460 and subsequently goes back to sleep because the MTIM frame 240 did not indicate that there is buffered broadcast and/or multicast data for station 1. The AP 14 transmits buffered broadcast frames to a third station (not shown) at 464. At 466, the AP 14 transmits buffered multicast data to the third station.

A third beacon 468 is transmitted that only contains the TIM field 214. However, neither station wakes up due to the respective listen intervals. A fourth beacon frame 470 that contains the DTIM frame is transmitted. The MTIM bit associated with station 2 is set in the fourth beacon 470. However, the MTIM bit associated with station 1 has not been set because station 1 is not interested in broadcast or multicast data. Station 1 wakes up at 472 to receive the fourth beacon frame 470 and subsequently goes back to sleep because its MTIM bit is not set. Station 2 wakes up at 474 to receive the fourth beacon frame 470. Since the MTIM bit associated with station 2 is set, station 2 stays awake to receive the broadcast data transmitted at 476 and the multicast data transmitted at 478. Station 2 goes back to sleep after receiving the buffered multicast traffic from the AP 14.

A fifth beacon 480 that only contains the TIM frame 214 is transmitted. However, station 1 and station 2 remain asleep due to the respective listen intervals. As shown in FIG. 18, when the AP 14 uses the multicast filter 234 to filter broadcast and/or multicast traffic on behalf of a client station, the client station can sleep longer and therefore consume less power.

In ad-hoc networks client stations use announcement traffic indication messages (ATIMs) to preempt other stations in the network from sleeping. Each station in the network periodically wakes up to receive a beacon and stays awake thereafter for an ATIM window. If a first station wishes to send traffic to a second station, the first station sends an ATIM frame during the ATIM window to notify the second station of the traffic. When the second station receives an ATIM frame, it stays awake for a subsequent ATIM window to receive the data from the first station. FIG. 19 depicts exemplary timing diagrams of client stations 26-1, 26-2, and 26-3 at 500, 502 and 504 respectively. The client stations 26-1, 26-2, and 26-3 periodically wake up for the ATIM window at 506 although there is not any data being transferred between them. Periodically waking up for the ATIM window and the beacon can be a significant drain of power on the client stations 26-1, 26-2, 26-3.

Referring now to FIG. 20, the client stations 26-1, 26-2, and 26-3 of the second wireless network 24 are operating in ad hoc mode and utilizing power saving modules according to some embodiments of the present invention. More specifically, each station 26-1, 26-2, and 26-3 may include a listen interval (LI) module 550, a contention avoidance (CA) module 552, a power save delivery (PSD) module 554, and an off-channel (OC) module 556.

The LI module 550 allows the client stations 26-1, 26-2, and 26-3 to choose a listen interval (LI) that corresponds to a number of beacon intervals that it will listen for an ATIM frame during the ATIM window. Each client station 26-1, 26-2, 26-3 may announce its respective listen interval to the other stations. To announce the listen interval, a special listen interval frame may be embedded in a beacon periodically generated by the client stations 26-1, 26-2, 26-3. Alternatively, each station 26-1, 26-2, 26-3 may send a special message to individual stations (i.e., unicast) or to multiple client stations 26-1, 26-2, 26-3 (i.e., multicast/broadcast).

## 13

The second network **24** may have an associated beacon number. The beacon number may be described with the following equation:

$$BN = \frac{TBTT}{BI}$$

where BN is the beacon number, TBTT is the target beacon transmission time of the beacon, and BI is the beacon interval. The LI module **550** activates a client station for the ATIM window when the beacon number is a multiple of its listen interval. More specifically, the LI module **550** activates a client station for the ATIM window when  $BN \bmod LI = 0$ . The LI module **550** tracks the listen interval of other client stations in the second network **24**. Therefore, a client station that wishes to transmit data to a second client station may wakeup to send an ATIM according to the listen interval of the second client station.

The CA module **552** allows the client stations **26-1**, **26-2**, **26-3** to cooperatively determine an ATIM transmission schedule. With the ATIM transmission schedule only one client station transmits during the ATIM window following the beacon. The ATIM transmission schedule helps to minimize and/or avoid contention and thus the ATIM window may be shorter. Shortening the ATIM window allows client stations that do not have data to receive to return to sleep quicker and helps reduce power consumption.

The CA module **552** tracks the number of stations in the second network **24** and assigns a unique identifier to its associated client station. The CA module **552** determines the ATIM transmission schedule based on the beacon number, the number of stations in the network, and the unique identifier. More specifically, the CA module **552** schedules the client station to transmit when:

$$BN \bmod N = SN$$

where BN is the beacon number, N is the total number of stations in the second network **24**, and SN is the unique identifier assigned to the client station. While a particular method is described herein for illustrative purposes, skilled artisans will appreciate that other methods may be used to determine the ATIM transmission schedule.

The PSD module **554** allows client stations in the second network **24** to negotiate a transmission schedule that is independent of the beacon and/or ATIM window. Thus, the PSD module **554** may allow two or more client stations to schedule transmissions at an interval that is longer than the beacon interval to reduce power consumption. To negotiate transmission schedule, a first client station may send a PSD frame (not shown) to a second client station. The PSD frame preferably includes a start time and a period. The start time allows the PSD module **554** to determine when to wake up the client station. The period allows the PSD module **554** to determine how often to wake up the client station to exchange data. Once the transmission schedule has been negotiated, the client stations wake up according to the schedule, exchange data and then go back to sleep.

Suppose, for example, that client stations **26-2** and **26-3** negotiate a transmission schedule with a start time of 1000 ms and a period of 20 ms. Both stations **26-2** and **26-3** may transition to the active mode at 1000 ms, exchange data, and then transition to the inactive mode until 1020 ms. At 1020 ms, stations **26-2** and **26-3** may wake up again, exchange data, and then go back to sleep until 1040 ms.

When operating in ad hoc mode, there may be situations when a client station may switch to a different frequency for

## 14

a brief period of time. For example, if a client station detects radar on the frequency of the network **24**, it may switch to a second frequency to obtain measurements in an attempt to find a frequency that is not interfering with the radar. When the client station switches to the second channel, it may send an off channel announcement (OCA) frame to the other stations informing them that it will not be unavailable for a period of time. The OCA frame may be broadcast and/or unicast to specific stations. If the client station returns to the frequency before the period of time has elapsed, it may send a cancel off channel announcement (COCA) frame. When the client stations are in power save mode, the OCA frame and the COCA frame need to be transmitted at a time when the other client stations will be awake to receive them.

The OC module **556** manages the transmission of the OCA frame and the COCA frame. More specifically, the OC module **556** determines when it may send the OCA and COCA frames so that the client stations in power save mode may receive the frames. In a typical power save scheme, the OC module **556** may send the OCA and COCA frame during the ATIM window following the beacon frame.

Referring now to FIG. **21**, the OC module **556** may implement steps generally identified at **600**. The process begins in step **602**. In step **604**, the OC module **556** determines whether a client station desires to switch to a different frequency. If the client station does not desire to switch to a different frequency, the process returns to step **604**. However, if the client station desires to switch to a different frequency, the OC module **556** determines whether it can transmit the OCA frame so that all stations will receive it in step **606**. If the OC module cannot transmit the OCA frame, the process returns to step **606**. Otherwise, the OC module **556** transmits the OCA frame in step **608**.

In step **610**, the client station may switch to a different frequency and obtain measurements. The OC module **556** determines whether the client station is finished measuring the different frequency in step **612**. If the client station is not finished measuring the different frequency, the process returns to step **610**. If the client station has finished measuring the different frequency, the OC module **556** determines whether the period of time associated with the OCA frame has elapsed in step **614**. If the period of time has elapsed, the process ends in step **616**. If the period of time has not elapsed, the OC module **556** determines whether it can send a COCA frame to all of the client stations in step **618**. If the OC module **556** cannot send a COCA frame to all the client stations, the process returns to step **614**. Otherwise, the OC module **556** sends a COCA frame to all the client stations in step **620** and the process ends in step **616**.

Referring now to FIG. **22**, exemplary timing diagrams **650**, **652**, **654** of client stations **26-1**, **26-2**, and **26-3** using the LI module **550** according to the present invention are illustrated. Stations **26-1**, **26-2**, and **26-3** have a listen interval of 1, 2, and 3 respectively. Although there is not any traffic being transferred between stations, each station periodically wakes up to transmit and/or receive an ATIM. Station **26-1** periodically wakes up at **506** to transmit and/or receive an ATIM. As shown, station **26-1** wakes up at the same interval as shown at **500** in FIG. **19** due to its listen interval. Station **26-2** has a listen interval of 2 and therefore wakes up every other ATIM window that follows a beacon as shown at **656**. Station **26-3** has a listen interval of 3 and therefore wakes up every third ATIM window that follows a beacon as shown at **658**. As shown, stations **26-2** and **26-3** wake up less often when using the LI module **550** and consequently consume less power.

Referring now to FIG. **23**, exemplary timing diagrams **700**, **702**, **704** of client stations **26-1**, **26-2**, and **26-3** using the CA

15

module 552 according to some embodiments the present invention are shown. As shown, the client stations 26-1, 26-2, and 26-3 periodically wake up for the ATIM window at 506 although there is not any data being transferred between them. However, due to the CA module 552 only one station is permitted to transmit for each ATIM window. The CA module 552 allows stations 26-1, 26-2, and 26-3 to transmit an ATIM at 706, 708, and 710 respectively. Since only one station transmits per ATIM window, there is extra time in each ATIM window that is not being utilized therefore the ATIM window may be reduced.

Referring now to FIG. 24, exemplary timing diagrams 750, 752, 754 of clients stations 26-1, 26-2, and 26-3 using the CA module 552 with a shorted ATIM window are shown. As shown the client stations 26-1, 26-2, and 26-3 periodically wake up at 756 to transmit and/or receive an ATIM frame. The time that the client stations 26-1, 26-2, and 26-3 are awake to transmit and/or receive an ATIM has been reduced due to the shortened ATIM window and therefore each client station consumes less power.

Referring now to FIG. 25, exemplary timing diagrams 800, 802, 804 of client stations 26-1, 26-2, and 26-3 using the LI module 550 and the CA module 552 according to some embodiments of the present invention are shown. Stations 26-1, 26-2, and 26-3 have a listen interval of 1, 2, and 3 respectively. Although there is not any traffic being transferred between stations, each station periodically wakes up for a shortened ATIM window to transmit and/or receive an ATIM frame. Station 26-1 periodically wakes up at 756 to transmit and/or receive an ATIM frame. As shown, station 26-1 wakes up at the same interval as shown at 506 in FIG. 19 due to its listen interval. Station 26-2 wakes up every other ATIM window that follows a beacon as shown at 806 due to its listen interval. Station 26-3 wakes up every third ATIM window that follows a beacon as shown at 808 due to its listen interval. As shown, stations 26-2 and 26-3 wake up less often when using the LI module 550 in addition to the CA module 552 and therefore consume less power.

Referring now to FIG. 26, exemplary timing diagrams 850, 852, and 854 of client stations 26-1, 26-2, and 26-3 are shown. Stations 26-2 and 26-3 are using the PSD module 554 and have determined a transmission schedule that is independent of the beacon and/or ATIM window. Station 26-1 periodically wakes up at 506 to transmit and/or receive ATIMs. However, stations 26-2 and 26-3 only wake up according to the transmission schedule at 856. As shown, stations 26-2 and 26-3 wake up less often than station 26-1 and therefore consume less power.

Referring now to FIGS. 26A-26G, various exemplary implementations of the present invention are shown. Referring now to FIG. 27A, the present invention can be implemented in a network accessed storage module (NAS) 901 that includes a hard disk drive 900. The present invention may implement and/or be implemented in a WLAN module, which is generally identified in FIG. 27A at 904. In some implementations, signal processing and/or control circuit 902 and/or other circuits (not shown) in the HDD 900 may process data, communicate with WLAN module 904, perform coding and/or encryption, perform calculations, and/or format data that is output to and/or received from a magnetic storage medium 906.

The HDD 900 may communicate with another networked device (not shown) such as a computer, a mobile computing device such as a personal digital assistant, cellular phone, media or MP3 player and the like, and/or other device via one or more wired links 908 and/or WLAN module 904. The HDD 900 may be connected to memory 909 such as random

16

access memory (RAM), low latency nonvolatile memory such as flash memory, read only memory (ROM) and/or other suitable electronic data storage. The HDD 900 may also include a power supply module 903.

Referring now to FIG. 27B, the present invention can be implemented in a digital versatile disc (DVD) drive 910. The present invention may implement and/or be implemented in a WLAN module which is generally identified in FIG. 27B at 911. Signal processing and/or control circuit 912 and/or other circuits (not shown) in the DVD drive 910 may process data, perform coding and/or encryption, perform calculations, and/or format data that is read from and/or data written to an optical storage medium 916. In some implementations, the signal processing and/or control circuit 912 and/or other circuits (not shown) in the DVD drive 910 can also perform other functions such as encoding and/or decoding and/or any other signal processing functions associated with a DVD drive.

The DVD drive 910 may communicate with an output device (not shown) such as a computer, television or other device via one or more wired links 917 and/or wireless links via WLAN module 911. The DVD drive 910 may communicate with mass data storage 918 that stores data in a nonvolatile manner. The mass data storage 918 may include a hard disk drive (HDD). The HDD may have the configuration shown in FIG. 27A. The HDD may be a mini HDD that includes one or more platters having a diameter that is smaller than approximately 1.8". The DVD drive 910 may be connected to memory 919 such as RAM, ROM, low latency nonvolatile memory such as flash memory and/or other suitable electronic data storage. The DVD drive 910 may also include a power supply 913.

Referring now to FIG. 27C, the present invention can be implemented in a high definition television (HDTV) 920. The present invention may implement and/or be implemented in either or both signal processing and/or control circuits, which are generally identified in FIG. 27E at 922, and a WLAN interface 929.

The HDTV 920 receives HDTV input signals in either a wired or wireless format and generates HDTV output signals for a display 926. In some implementations, signal processing circuit and/or control circuit 922 and/or other circuits (not shown) of the HDTV 920 may process data, perform coding and/or encryption, perform calculations, format data and/or perform any other type of HDTV processing that may be required.

The HDTV 920 may communicate with mass data storage 927 that stores data in a nonvolatile manner such as optical and/or magnetic storage devices. At least one HDD may have the configuration shown in FIG. 27A and/or at least one DVD may have the configuration shown in FIG. 27B. The HDD may be a mini HDD that includes one or more platters having a diameter that is smaller than approximately 1.8". The HDTV 920 may be connected to memory 928 such as RAM, ROM, low latency nonvolatile memory such as flash memory and/or other suitable electronic data storage. The HDTV 920 also may include a power supply 923.

Referring now to FIG. 27D, the present invention may implement and/or be implemented in a WLAN interface 948 of a vehicle 930. A powertrain control system 932 receives inputs from one or more sensors such as temperature sensors, pressure sensors, rotational sensors, airflow sensors and/or any other suitable sensors and/or that generates one or more output control signals such as engine operating parameters, transmission operating parameters, and/or other control signals.

The present invention may also be implemented in other control systems 940 of the vehicle 930. The control system

17

940 may likewise receive signals from input sensors 942 and/or output control signals to one or more output devices 944. In some implementations, the control system 940 may be part of an anti-lock braking system (ABS), a navigation system, a telematics system, a vehicle telematics system, a lane departure system, an adaptive cruise control system, a vehicle entertainment system such as a stereo, DVD, compact disc and the like. Still other implementations are contemplated.

The powertrain control system 932 may communicate with mass data storage 946 that stores data in a nonvolatile manner. The mass data storage 946 may include optical and/or magnetic storage devices for example hard disk drives HDD and/or DVDs. At least one HDD may have the configuration shown in FIG. 27A and/or at least one DVD may have the configuration shown in FIG. 27B. The HDD may be a mini HDD that includes one or more platters having a diameter that is smaller than approximately 1.8". The powertrain control system 932 may be connected to memory 947 such as RAM, ROM, low latency nonvolatile memory such as flash memory and/or other suitable electronic data storage. The powertrain control system 932 also may support connections with a WLAN via WLAN interface 948. Vehicle 930 may also include a power supply 933.

Referring now to FIG. 27E, the present invention can be implemented in a cellular phone 950 that may include a cellular antenna 951. The present invention may implement and/or be implemented in a WLAN interface 968. In some implementations, the cellular phone 950 includes a microphone 956, an audio output 958 such as a speaker and/or audio output jack, a display 960 and/or an input device 962 such as a keypad, pointing device, voice actuation and/or other input device. The signal processing and/or control circuits 952 and/or other circuits (not shown) in the cellular phone 950 may process data, perform coding and/or encryption, perform calculations, format data and/or perform other cellular phone functions.

The cellular phone 950 may communicate with mass data storage 964 that stores data in a nonvolatile manner such as optical and/or magnetic storage devices for example hard disk drives HDD and/or DVDs. At least one HDD may have the configuration shown in FIG. 27A and/or at least one DVD may have the configuration shown in FIG. 27B. The HDD may be a mini HDD that includes one or more platters having a diameter that is smaller than approximately 1.8". The cellular phone 950 may be connected to memory 966 such as RAM, ROM, low latency nonvolatile memory such as flash memory and/or other suitable electronic data storage. The cellular phone 950 also may support connections with a WLAN via WLAN interface 968. Cellular phone 950 may also include a power supply 953.

Referring now to FIG. 27F, the present invention can be implemented in a set top box 480. The present invention may implement and/or be implemented in a WLAN interface 996. The set top box 980 receives signals from a source such as a broadband source and outputs standard and/or high definition audio/video signals suitable for a display 988 such as a television and/or monitor and/or other video and/or audio output devices. The signal processing and/or control circuits 984 and/or other circuits (not shown) of the set top box 980 may process data, perform coding and/or encryption, perform calculations, format data and/or perform any other set top box function.

The set top box 980 may communicate with mass data storage 990 that stores data in a nonvolatile manner. The mass data storage 990 may include optical and/or magnetic storage devices for example hard disk drives HDD and/or DVDs. At least one HDD may have the configuration shown in FIG.

18

27A and/or at least one DVD may have the configuration shown in FIG. 27B. The HDD may be a mini HDD that includes one or more platters having a diameter that is smaller than approximately 1.8". The set top box 980 may be connected to memory 994 such as RAM, ROM, low latency nonvolatile memory such as flash memory and/or other suitable electronic data storage. The set top box 980 also may support connections with a WLAN via WLAN interface 996. Set top box 980 may also include a power supply 983.

Referring now to FIG. 27G, the present invention can be implemented in a media player 1000. The present invention may implement and/or be implemented in a WLAN interface 1016. In some implementations, the media player 1000 includes a display 1007 and/or a user input 1008 such as a keypad, touchpad and the like. In some implementations, the media player 1000 may employ a graphical user interface (GUI) that typically employs menus, drop down menus, icons and/or a point-and-click interface via the display 1007 and/or user input 1008. The media player 1000 further includes an audio output 1009 such as a speaker and/or audio output jack. The signal processing and/or control circuits 1004 and/or other circuits (not shown) of the media player 1000 may process data, perform coding and/or encryption, perform calculations, format data and/or perform any other media player function.

The media player 1000 may communicate with mass data storage 1010 that stores data such as compressed audio and/or video content in a nonvolatile manner. In some implementations, the compressed audio files include files that are compliant with MP3 format or other suitable compressed audio and/or video formats. The mass data storage may include optical and/or magnetic storage devices for example hard disk drives HDD and/or DVDs. At least one HDD may have the configuration shown in FIG. 27A and/or at least one DVD may have the configuration shown in FIG. 27B. The HDD may be a mini HDD that includes one or more platters having a diameter that is smaller than approximately 1.8". The media player 1000 may be connected to memory 514 such as RAM, ROM, low latency nonvolatile memory such as flash memory and/or other suitable electronic data storage. The media player 1000 also may support connections with a WLAN via WLAN interface 1016. Media player 1000 may also include a power supply 1013. Still other implementations in addition to those described above are contemplated.

Those skilled in the art can now appreciate from the foregoing description that the broad teachings of the present invention can be implemented in a variety of forms. Therefore, while this invention has been described in connection with particular examples thereof, the true scope of the invention should not be so limited since other modifications will become apparent to the skilled practitioner upon a study of the drawings, the specification and the following claims.

What is claimed is:

1. An access point configured to be implemented in a wireless network, wherein the access point is configured to communicate with one or more client stations in the wireless network, the access point comprising:

a beacon circuit configured to generate (i) a first beacon and (ii) a second beacon, wherein the first beacon is smaller in size than the second beacon;

a transmitter configured to periodically transmit, to the one or more client stations in the wireless network, each of the first beacon and the second beacon, wherein each time the first beacon and the second beacon are transmitted by the transmitter, the first beacon is transmitted prior to the second beacon; and

19

a link circuit configured to establish a link with a first client station of the one or more client stations;  
 wherein the first client station is configured to operate in (i) an active mode and (ii) a power save mode; and  
 wherein in response to establishing the link with the access point, the first client station is configured to transition from the power save mode to the active mode to receive the first beacon rather than the second beacon;  
 determine, based on the first beacon, whether the access point has data for the first client station; and  
 transition from the active mode to the power save mode in response to determining that the access point does not have data for the first client station.

2. The access point of claim 1, wherein the first beacon includes a less number of fields than the second beacon.

3. The access point of claim 1, wherein:  
 the first beacon includes (i) a first header, (ii) a first time stamp, and (iii) a first traffic indication map; and  
 the second beacon includes (i) a second header, (ii) a second time stamp, (iii) a second traffic indication map, and (iv) at least one additional field than the first beacon.

4. The access point of claim 1, wherein the transmitter is configured to:  
 periodically transmit the second beacon at a target beacon transmission time; and  
 complete transmission of the first beacon before the target beacon transmission time.

5. The access point of claim 1, wherein the transmitter is configured to transmit the second beacon after the first beacon without any back-off in between.

6. The access point of claim 1, further comprising a filter configured to:  
 receive a signal from a first client station of the one or more client stations; and  
 determine, based on the signal, whether data received by the access point is of interest to the first client station.

7. The access point of claim 6, wherein:  
 the filter is configured to discard the data in response to the data being of no interest to the first client station; and  
 the first client station is configured to transition from the power save mode to the active mode to receive the first beacon, and  
 transition from the active mode to the power save mode after receiving the first beacon in response to the data being of no interest to the first client station.

8. The access point of claim 6, wherein:  
 the filter is configured to include an indication in the first beacon in response to the data being of interest to the first client station; and  
 the first client station is configured to transition from the power save mode to the active mode to receive the first beacon, and  
 remain in the active mode after receiving the first beacon to receive the data in response to the data being of interest to the first client station.

9. The access point of claim 6, wherein:  
 the filter is configured to generate, based on the signal and in response to the data being of interest to the first client station, a response on behalf of the first client station without requiring the first client station to transition from the power save mode to the active mode to (i) receive the data and (ii) generate the response.

10. A method for periodically transmitting beacons from an access point to one or more client stations in a wireless network, the method comprising:

20

generating, at the access point, (i) a first beacon and (ii) a second beacon, wherein the first beacon is smaller in size than the second beacon;  
 periodically transmitting, from the access point to the one or more client stations in the wireless network, each of the first beacon and the second beacon, wherein periodically transmitting each of the first beacon and the second beacon comprises transmitting the first beacon prior to the second beacon;  
 establishing a link with a client station configured to operate in (i) an active mode and (ii) a power save mode;  
 transitioning the client station from the power save mode to the active mode to receive the first beacon rather than the second beacon;  
 determining, based on the first beacon, whether the access point has data for the client station; and  
 transitioning the client station from the active mode to the power save mode in response to determining that the access point does not have data for the client station.

11. The method of claim 10, wherein the first beacon includes a less number of fields than the second beacon.

12. The method of claim 10, wherein:  
 the first beacon includes (i) a first header, (ii) a first time stamp, and (iii) a first traffic indication map; and  
 the second beacon includes (i) a second header, (ii) a second time stamp, (iii) a second traffic indication map, and (iv) at least one additional field than the first beacon.

13. The method of claim 10, wherein periodically transmitting each of the first beacon and the second beacon comprises:  
 transmitting the second beacon at a target beacon transmission time; and  
 completing transmission of the first beacon before the target beacon transmission time.

14. The method of claim 10, wherein periodically transmitting each of the first beacon and the second beacon comprises transmitting the second beacon after the first beacon without any back-off in between.

15. The method of claim 10, further comprising:  
 receiving, at the access point, a signal from a client station; and  
 determining, based on the signal, whether data received by the access point is of interest to the client station.

16. The method of claim 15, further comprising:  
 discarding the data in response to the data being of no interest to the client station;  
 transitioning the client station from the power save mode to the active mode to receive the first beacon; and  
 transitioning the client station from the active mode to the power save mode after receiving the first beacon in response to the data being of no interest to the client station.

17. The method of claim 15, further comprising:  
 including an indication in the first beacon in response to the data being of interest to the client station;  
 transitioning the client station from the power save mode to the active mode to receive the first beacon; and  
 allowing the client station to stay in the active mode after receiving the first beacon to receive the data in response to the data being of interest to the client station.

18. The method of claim 15, further comprising:  
 generating, at the access point, based on the signal and in response to the data being of interest to the client station, a response on behalf of the client station without requiring

**21**

ing the client station to transition from the power save mode to the active mode to (i) receive the data and (ii) generate the response.

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**22**